Chapter 18b: Assessment of the sharks in the Bering Sea and Aleutian Islands

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EXECUTIVE SUMMARY

Summary of Major Changes

Changes to the input data

1. Total catch for BSAI sharks is updated to include 2010 (as of Oct 10, 2010)
2. NMFS longline and IPHC survey data has been updated.
3. An examination of the spatial patterns of observed catch was added to the incidental catch section and a similar analysis of survey data was included in the other data sources section.
4. Alternatives to the average catch history Tier 6 method are presented.

Changes in assessment methodology

At the September 2010 Plan Team meeting, the joint plan teams discussed alternative methods for estimating ABC and OFL for Tier 6 species. Based on that discussion and recommendations by the SSC, five alternatives to the current Tier 6 method (OFL = average catch 1997 - 2007 and ABC = 0.75*OFL) are presented in the ABC and OFL calculations sections. Alternatives include OFL = maximum catch, and OFL = 70th, 80th, or 90th percentile of the catch history.

Summary of Results

There is no evidence to suggest that overfishing is occurring for any shark species in the BSAI. Total shark catch in 2009 was 144 t and in 2010 was 40 t as of October 10, 2010. We continue to recommend that sharks be managed as Tier 6 species with the ABC and OFL based on the average catch 1997 - 2007. This results in an ABC of 449 t and an OFL of 598 t for the shark complex combined. Catch in 2009 of all sharks was 144 t and 40 t in 2010 (as of October 10, 2010). At this time, we do not recommend taking actions to change the Tier 6 calculations that would increase the catch limits of sharks. There are two primary issues of concern here: 1) bycatch of sharks in the halibut IFQ fishery; and 2) unidentified sharks. We suggest re-evaluating the Tier 6 calculations after these issues have been addressed. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI, and most incidentally captured sharks are not retained. Sharks have only been reported to species in the catch since 1997 and have made up from 1% to 5% of Other Species catch from 1997 – 2010. Pacific sleeper shark make up 68% of the total shark catch in the BSAI, followed by Other/unidentified sharks at 20%, salmon shark at 9% and spiny dogfish at 2%.

ABC and OFL Calculations and Tier 6 recommendations for 2011-2012

Shark Complex – All Species Combined	**Last year**		**This year**	
Quantity/Status	2010	2011	**2011**	2012
M (natural mortality)	0.097	0.097	**0.097**	0.097
Specified/recommended Tier	6	6	**6**	6
Specified/recommended OFL (t)	598	598	**598**	598
Specified/recommended ABC (t)	449	449	**449**	449
Is the stock being subjected to overfishing?	NA*	NA*	NA*	NA*
*Data are not available to determine whether stocks are overfished for Tier 6 stocks,				

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unidentified shark	**Total shark Complex**
Tier	6	6	6	6	6
M	0.097	unknown	0.18	unknown	0.097
Average catch (1997-2007) (t)	8	416	48	126	598
Recommended ABC (t)	6	312	36	95	449
Recommended OFL (t)	8	416	48	126	598

Responses to SSC Comments

Responses to SSC comments specific to this assessment
From the December 2009 SSC minutes:

The SSC supports the four plan team recommendations on pg. 16 of the November 2009 Plan Team minutes:

1) *Evaluate how to better estimate bycatch by using both fishery and survey data from halibut (fishery or surveys)*
2) *Examination of raw observer data of catch (especially in 2004) be done prior to extrapolation given variability in catch records*
3) *Evaluate potential for Tier 5 assessment for spiny dogfish and sleeper sharks. Note that no M estimate for sleeper sharks currently available.*

1) This topic is being investigated in a separate working group and catch estimates will be available for the next assessment. See the report titled "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet"
2) Observer data has been plotted to examine spatial patterns of high bycatch (Figures 3-5) and to help delineate the "other/unidentified sharks" (in the incidental catch section).
3) A discussion of the possibility of moving spiny dogfish to Tier 5 is included in the ABC and OFL calculations section. We do not recommend moving spiny dogfish to Tier 5 because of the poor biomass estimates and because unobserved fisheries are not accounted for in the catch history yet. Data do not support Tier 5 for Pacific sleeper shark because there is not estimate of natural mortality and survey biomass estimates are not reliable.

The SSC also recommends adding a research priority on the development of aging methods for Pacific sleeper sharks. So that M and other life history parameters can be estimated for future assessments.

This has been added as a research priority. A pilot study took place in October at the REFM age and growth lab examining a potential method for aging Pacific sleeper sharks, as well as improving aging methods for spiny dogfish. Methods for aging Pacific sleeper sharks have also been investigated by one of the assessment authors (K. Goldman) at ADF&G. Aging of Pacific sleeper sharks is very difficult because their hard structures (vertebrae, jaws, etc.) do not calcify well and to date none of the attempted methods have been able to elucidate readable banding patterns.

The results of Rice's (2007) master's thesis on spiny dogfish, such as biomass estimates relative to virgin biomass, should be referenced in the chapter. His findings may be relevant to discussions about the difficulty using the NMFS biannual trawl survey to estimate dogfish biomass.

Rice's M.S. thesis has been referenced in the discussion of the trawl survey spiny dogfish biomass estimates. Efforts are underway to build off his work to incorporate biomass models into future assessments.

The SSC supports further development of both proposed methods to estimate shark bycatch in halibut fisheries reported in the Appendix. When completed, reconstructed historical estimates of shark catch should be added to the historical catch time-series for sharks.

A working group was formed in early 2010 to further investigate methods to estimate bycatch of all non-target species in the unobserved portion of the halibut fleet. The working group report is a separate document titled: "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet" and will be presented at the November Plan Team meeting.

The SAFE chapter authors should consider shark bycatch in state-managed fisheries, such as salmon gillnets and groundfish longline fisheries for cod and sablefish. The authors should explore ways to extend bycatch estimates to the state managed longline fisheries. For instance, the same approach used to extend halibut survey bycatches of sharks to the halibut fishery could perhaps be applied to ADF&G longline surveys for sablefish in Southeast Alaska. Regarding salmon fisheries, such an approach may be unlikely, but shark bycatch could at least be characterized by ADF&G area managers.

We concur. Shark bycatch in state-managed salmon gillnet and seine fisheries is an issue of concern and has been brought before the Board of Fish. Bycatch data does not exist for those fisheries, but the SAFE authors have been discussing options with area managers.

INTRODUCTION

Squalus acanthias is the taxonomic classification that has been used for the spiny dogfish of the North Pacific and many areas of the world, however, the *S. acanthias* "group" is not monospecific and has a history of being taxonomically challenging. The North Pacific spiny dogfish were reclassified by Girard (1854) as *S. suckleyi*, but the description was vague and no type specimens were preserved, thus it remained *S. acanthias* until recently. This year, *S. suckleyi* was resurrected based on morphological, meristic and molecular data (Ebert et al. 2010). Beginning in 2010, spiny dogfish will be classified as *S. suckleyi* in the SAFE, but both names may be used to be consistent with data sources (e.g. RACEBASE survey data).

Alaska Fisheries Science Center (AFSC) bottom trawl surveys and fishery observer catch records provide information on sharks that occur in the Bering Sea and Aleutian Islands (BSAI) (Table 1, Figure 1). The three shark species most likely to be encountered in BSAI fisheries and surveys are two members of the family Squalidae, the Pacific sleeper shark (*Somniosus pacificus*) and the piked or spiny dogfish, and the salmon shark (*Lamna ditropis*). A history of the management measures taken for the other species group and shark complex is summarized in Table 2.

General Distribution

<u>Spiny Dogfish</u>

Spiny dogfish are semi-pelagic but demersal at times, occupying shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the North Pacific, and worldwide in non-tropical waters. They are considered more common off the U.S. west coast and British Columbia (BC) than in the GOA or Bering Sea and Aleutian Islands (Hart 1973, Ketchen 1986, Mecklenburg et al. 2002). Spiny dogfish inhabit benthic environments to depths of 677 m (Tribuzio, unpublished data), but are often found in the water column and at surface waters (Tribuzio, unpublished data). This species may once have been the most abundant living shark (Mecklenburg et al. 2002). However, it is commercially fished worldwide and has been heavily depleted in many locations. Directed fisheries for spiny dogfish are often selective on larger individuals (mature females), resulting in significant impacts on reproductive potential (Hart 1973, Sosebee 1998).

Pacific Sleeper Shark

Pacific sleeper sharks (*Somniosus spp*.) range as far north as the Arctic Circle in the Chukchi Sea (Benz et al. 2004), west off the Asian coast and the western Bering Sea (Orlov and Moiseev 1999), and south along the Alaskan and Pacific coast and possibly as far south as the coast of South America (de Astarloa et al. 1999). However, Yano et al. (2004) reviewed the systematics of sleeper sharks and suggested that sleeper sharks in the southern hemisphere and the southern Atlantic were misidentified as Pacific sleeper sharks and are actually *Somniosus antarcticus*, a species of the same subgenera. Pacific sleeper sharks have been documented at a wide range of depths, from surface waters (Hulbert et al. 2006) to 5,700 ft (seen on a planted grey whale carcass off Santa Barbara, CA, www.nurp.noaa.gov/Spotlight/Whales.htm). Pacific sleeper sharks are found in relatively shallow waters at higher latitudes and in deeper habitats in temperate waters (Yano et al. 2007).

Salmon Shark

Salmon sharks range in the North Pacific from Japan through the Bering Sea and Gulf of Alaska to southern California and Baja, Mexico. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Salmon sharks are rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI. In other areas, salmon sharks have been considered a nuisance because they eat salmon and damage fishing gear (Macy et al. 1978, Compagno 1984). They have been investigated as potential target species in the Gulf of Alaska; however they are currently only targeted by sport fishermen in state recreational fishery, mostly in Prince William Sound (Paust and Smith 1989).

Management Units

Sharks have been managed in aggregate as part of the "Other Species" complex in the BSAI Fishery Management Plan (FMP) (Gaichas et al. 1999, Gaichas 2003). The Other Species complex includes sharks, skates, sculpins, and octopus. An aggregate annual quota limits Other Species catch under an interim management policy for the BSAI. Because data for these species are sparse, acceptable biological catch (ABC) and overfishing levels (OFL) are usually based on Tier 5 and Tier 6 criteria (Table 2). Total allowable catch (TAC) for the Other Species complex was constrained by the BSAI optimum yield (OY) cap of 2 million metric tons. In response to the requirements for annual catch limits contained within the reauthorization of the Magnuson Stevens Fishery Conservation and Management Act, the NPFMC reviewed the management of other species in the BSAI. The NPFMC passed amendment 87 (http://www.fakr.noaa.gov/sustainablefisheries/amds/95-96-87/amd87.pdf) to the BSAI FMP that requires sharks be managed as a separate complex and that Annual Catch Limits (ACLs) would be established annually by the SSC starting in 2011.

Evidence of Stock Structure

Spiny Dogfish

Information on the spiny dogfish in the BSAI is limited, thus we assume biological characteristics from GOA studies are similar. Previous studies have shown complex population structure for spiny dogfish populations in other areas. Tagging studies show separate migratory populations that mix seasonally on feeding grounds in the United Kingdom. British Columbia and Washington State have both local and migratory populations that mix at a very small rate (Compagno 1984, McFarlane and King 2003). The migratory populations of spiny dogfish may undertake large-scale migrations, with tag recoveries ranging from British Columbia to Japan or Mexico (McFarlane and King 2003). Spiny dogfish tend to segregate by sex and by size, large, adult males and large females are generally separate, and large sub-adults and small mature adults of both sexes tend to mix. The observed age structure in the GOA ranges from 8-50 years, and all areas of the GOA have generally the same age structure (Tribuzio et al. 2010).

Pacific Sleeper Shark

Little is known about Pacific sleeper shark migratory behavior or their life history, especially in the BSAI. However, there have been some tagging studies in the central Gulf of Alaska (GOA) that show that at least some Pacific sleeper sharks reside in the Gulf of Alaska and Prince William Sound throughout the year, where they exhibit relatively limited geographic movement (< 100 km; Hulbert et al. 2006). In the GOA, Pacific sleeper sharks commonly migrate vertically throughout the water column (Orlov and Moiseev 1999, Hulbert et al. 2006), but did not migrate far from initial tagging locations (Hulbert et al. 2006). Median distance traveled for conventionally tagged sharks was 29.2 km, and median time at liberty was 1,729 days (Courtney and Hulbert 2007). Median vertical movement rate calculated from 4,781 hours of recorded depth data from one shark was 6 km/day (Hulbert et al. 2006). Similarly, sharks with acoustic tags in Southeast Alaska were tracked at depths greater than 500 m and made vertical migrations off the bottom (Courtney and Hulbert 2007). Another tracked shark also made horizontal movements of 6 km/day (Courtney and Hulbert 2007).

Salmon Shark

Salmon sharks differ by length-at-maturity, age-at-maturity, growth rates, weight-at-length, and sex ratios between the western North Pacific Ocean (WNP) and the eastern North Pacific Ocean (ENP) separated by longitude 180^{o} (Goldman and Musick 2006), including the Bering Sea. In the WNP, a salmon shark pupping and nursery ground may exist just north of the transitional domain in oceanic waters, a band of high productivity at the southern boundary of the sub-arctic domain (~40-45˚N) of the North Pacific Ocean. According to Nakano and Nagasawa (1996), juveniles (70-110 cm PCL, slightly larger than term embryos) were caught in waters with SST's of 14^{o}-16^{o}C, with adults occurring in colder waters further north. Another pupping and nursery area may exist in the ENP from southeast Alaska to northern Baja California, Mexico in near coastal waters (Goldman and Musick 2006, 2008).

Life History Information

Sharks are long-lived species with slow growth to maturity, a large maximum size, and low fecundity. Therefore, the productivity of shark populations is very low relative to most commercially exploited teleosts (Holden 1974 and 1977, Compagno 1990, Hoenig and Gruber 1990). Shark reproductive strategies in general are characterized by long gestation periods (6 months - 2 years), with small numbers of large, well-developed offspring (Pratt and Casey 1990). Perhaps because of these life history characteristics, large-scale directed fisheries for sharks have collapsed, even where management was attempted (Anderson 1990, Hoff and Musick 1990, Castro et al. 1999). In 2009, staff at AFSC calculated vulnerability scores for 41 BSAI species based on life history characteristics, distribution and susceptibility to fisheries (http://www.afsc.noaa.gov/refm/docs/2009/GOAvulnerability.pdf). Sharks were 3 of the 5 most vulnerable species, with salmon shark least vulnerable at 1.96 (lower scores are less vulnerable), spiny dogfish at 2.10 and Pacific sleeper shark at 2.24, the most vulnerable of all BSAI species calculated.

Spiny Dogfish

Eastern North Pacific spiny dogfish grow to a relatively large maximum size of 160 cm (Compagno 1984). Spiny dogfish are rarely captured in BSAI trawl and longline surveys, thus length data is based on GOA data. The average length of spiny dogfish caught in GOA biennial trawl surveys was 77.8 cm TL_{ext} for females (measured from the tip of the snout to the tip of the upper caudal lobe with the tail depressed to align with the horizontal axis of the body), and 75.4 cm TL_{ext} for males (N = 1,770 females and N = 3,044 males, all survey years combined, Figure 2). The average length for females sampled in the 2010 annual longline survey (first year of length data for this survey) was 65 cm TL_{ext} for females and 63 cm TL_{ext} for males (N = 378 females and N = 243 males, Figure 2). Average size of females collected during a 2006 special project with the observer program was 81.9 cm TLext and 79.6 cm TLext for males (N = 604 females and N = 528 males Figure 2).

Historic estimates of spiny dogfish age-at-50%-maturity for the ENP range from 20 to 34 years. Ages-at-50%-maturity for BC spiny dogfish is reported at 35 years for females, and 19 years for males (Saunders and McFarlane 1993). Ages from the spines of oxytetracycline-injected animals provided validation of an age-length relationship (Beamish and McFarlane 1985, McFarlane and Beamish 1987). The ages of ENP spiny dogfish have further been validated by bomb radiocarbon (Campana et al. 2006). The same study suggested that longevity in the ENP is between 80 and 100 years and that several earlier published ages-at-maturity (and therefore longevity) were low due to agers rejecting difficult-to-read spines and spine annuli that were grouped very close together. Age-at-maturity is similar in the GOA, 34 years for females and 19 years for males (Tribuzio, unpublished data). Growth rates for this species are among the slowest of all shark species, κ=0.03 for females and 0.06 for males (Tribuzio et al. 2010).

The mode of reproduction for spiny dogfish is aplacental viviparity. Embryos are nourished by their yolk sac while being retained in utero for 18-24 months. Reproductive and maturity data is available for areas in the GOA and further south, but not in the BSAI. Ketchen (1972) reported timing of parturition in BC to be October through December and in the Sea of Japan parturition occurred between February and April (Kaganovskaia 1937, Yamamoto and Kibezaki 1950, Anon 1956). Washington State spiny dogfish have a long pupping season, which peaks in October and November (Tribuzio 2004). In the GOA, pupping may occur during winter months, based on the size of embryos observed during summer and fall sampling (Tribuzio, pers. obs.). Pupping is believed to occur in estuaries and bays or mid-water over depths of about 165 - 370 m (Ketchen 1986). Small juveniles and young of the year tend to inhabit the water column near the surface or areas not fished commercially. Therefore juveniles are not available to commercial fisheries until they grow or migrate to fished areas (Beamish et al. 1982, Tribuzio and Kruse, in review). The average litter size is 6.9 pups for spiny dogfish in Puget Sound, WA (Tribuzio 2004), 6.2 in BC (Ketchen 1972) and 9.7 in the GOA (Tribuzio and Kruse, in review). The number of pups per female also increases with the size of the female, with estimates ranging from 0.20 – 0.25 more pups for every centimeter in length after the onset of maturity (Ketchen 1972, Tribuzio 2004, Tribuzio and Kruse, in review).

Pacific Sleeper Sharks

Sleeper sharks (*Somniosus* spp.) can attain large sizes, most likely possess a slow-growth rate and are likely long-lived (Fisk et al. 2002), however, very little data is available on Pacific sleeper shark life history. The average lengths of *Somniosus* sp. (possibly Greenland shark, *Somniosus microcephalus*) captured in mid-water trawls in the Southern Ocean off the outer shelf and upper continental slope of subantarctic islands are 390 cm TL (total length with the tail in the natural position, range 150-500 cm, n=36, Cherel and Duhamel 2004). Large *Somniosus* sharks observed in photographs from deep water have been estimated at lengths up to 700 cm (Compagno 1984). The maximum lengths of captured Pacific sleeper sharks are 440 cm for females and 400 cm for males (Mecklenburg et al. 2002). Pacific sleeper sharks have been measured on AFSC longline surveys (2001 and 2002) and during biannual trawl surveys. Longline caught female Pacific sleeper sharks averaged 170 cm (N = 119) PCL (pre-caudal length, measured from the tip of the snout to the pre-caudal notch) and 166 cm (N = 79) PCL for males

(Sigler et al. 2006). Sample size was low in bottom trawl survey samples so sexes were combined, average length was 270 cm (N = 74) PCL. Pacific sleeper sharks as large as 430 cm have been caught in the northwestern Pacific Ocean, where they were found to have sexual dimorphism, with females being shorter and heavier (avg. length = 138.9 cm, avg. weight = 28.4 kg) than males (avg. length = 140 cm, avg. weight = 23.7 kg) (Orlav 1999). The cartilage in sleeper sharks does not calcify to the degree of many other shark species, therefore aging is difficult and methods of age validation are under investigation. A Greenland shark, was sampled in 1999 and was determined to be alive during the 1950's-1970's because it had high levels of DDT, which was used as an insecticide during this period (Fisk et al. 2002).

Published observations suggest that mature female Pacific sleeper sharks are in excess of 365 cm TL, mature males are in excess 397 cm TL, and that size at birth is approximately 40 cm TL (Gotshall and Jow 1965, Yano et al. 2007). However, only five mature female Pacific sleeper sharks have been documented in the literature. The reproductive mode of Pacific sleeper sharks is thought to be aplacental viviparity. Three mature females 370-430 cm long were opportunistically sampled off the coast of California. In one of these specimens several thousand small eggs (<10mm) as well as 372 large vascularized eggs (24 - 50mm) were present in the ovaries (Ebert et al. 1987). Another mature Pacific sleeper shark 370 cm long was caught off Trinidad California (Gotshall and Jow 1965). The ovaries contained 300 large unfertilized eggs and many small undeveloped ova. Diameters of the large eggs ranged from 45 to 58 mm. Additionally, a single mature female was found off the Kuril Islands, northeast of Hokkaido, Japan, that measured 423 cm long (Orlov 1999). Two recently-born 74 cm sharks have been caught off the coast of California at 1300 and 390 m depth; one still had an umbilical scar (Ebert et al. 1987). Unfortunately, the date of capture was not reported. A newly born shark of 41.8 cm was also caught at 35 m depth off Hiraiso, Ibaraki, Japan (Yano et al. 2007). Additionally, three small Pacific sleeper sharks, 65 - 75 cm long, have been caught in the Northwest Pacific, but the date of sampling was not reported (Orlov and Moiseev 1999). In 2005, an 85 cm (pre-caudal length) female was caught during the annual sablefish longline survey near Yakutat Bay and in 2009 another 85 cm PCL female was caught by a commercial halibut fisherman inside Chatham Strait in Southeast Alaska (Tribuzio unpublished data). Because of a lack of observations of mature and newly born sharks, and the absence of dates in the literature, the spawning and pupping season is unknown for Pacific sleeper sharks.

Salmon Shark

Like other sharks of the family Lamnidae, salmon sharks are active and highly mobile, maintaining body temperatures as high as 21.2 ^{o}C above ambient water temperatures and apparently maintaining a constant body core temperature regardless of ambient temperatures (Goldman 2002, Goldman et al. 2004). Adult salmon sharks typically range in size from 180 - 210 cm PCL (Goldman 2002, Goldman and Musick 2006) in the ENP and can weigh upwards of 220 kg. Lengths of 260 cm PCL (300 cm TL) and greater and weights exceeding 450 kg are rumored but unsubstantiated (Goldman and Musick 2008). Length-at-maturity in the WNP has been estimated to occur at approximately 140 cm pre-caudal length (PCL) for males and 170 - 180 cm PCL for females (Tanaka 1980). These lengths correspond to ages of approximately 5 years and 8 - 10 years, respectively. Length-at-maturity in the ENP is estimated to occur between 125 - 145 cm PCL (age three to five) for males and between 160-180 cm PCL (age six to nine) for females (Goldman 2002, Goldman and Musick 2006). Tanaka (1980, see also Nagasawa 1998) states that maximum age from vertebral analysis for WNP salmon shark is at least 25 years for males and 17 years for females, and the von Bertalanffy growth coefficients (κ) for males and females are 0.17 and 0.14, respectively. Goldman (2002) and Goldman and Musick (2006) gave maximum ages for ENP salmon shark (also from vertebral analysis) of 17 years for males and 30 years for females (Goldman, unpublished data), with growth coefficients of 0.23 and 0.17 for males and females, respectively. Longevity estimates are similar (20-30 years) for the ENP and WNP. Salmon sharks in the ENP and WNP attain the same maximum length (approximately 215 cm PCL for females and about 190 cm PCL for males). However, males past approximately 140 cm PCL and females past approximately 110 cm PCL in the ENP are of a greater weight-at-length than their same-sex counterparts in the WNP (Goldman 2002, Goldman and Musick 2006).

The reproductive mode of salmon sharks is aplacental viviparity and includes an oophagous stage in which embryos feed on eggs produced by the ovary (Tanaka 1986 cited in Nagasawa 1998). Litter size in the western Pacific is four to five pups, and litters have been reported to be male dominated in a 2.2:1 ratio (Nagasawa 1998), but this is from a very limited sample size. In the eastern Pacific, a pregnant female salmon shark caught near Kodiak Island had four pups: two males and two females (Gallucci et al. 2008). Gestation times throughout the North Pacific appear to be nine months, with mating occurring during the late summer and early fall and parturition occurring in the spring (Tanaka 1986, Nagasawa 1998, Goldman 2002, Goldman and Human 2004, Goldman and Musick 2006). Size at parturition is between 60 - 65 cm PCL in both the ENP and WNP (Tanaka 1980, Goldman 2002, Goldman and Musick 2006).

FISHERY

Commercial

There are currently no directed commercial fisheries for shark species in federally- or state- managed waters of the BSAI.

Bycatch, Discards, and Historical Catches

Historical catches of sharks in the BSAI are composed entirely of incidental catch, and nearly all incidental shark catch is discarded. Mortality rates of discarded catch are unknown, but are conservatively estimated in this report as 100%. Aggregate incidental catches of the Other Species management category from federally prosecuted fisheries for Alaskan groundfish in the BSAI are tracked in-season by NMFS AKRO (Table 2). Discard rates for sharks are presented in Table 4. Most sharks are discarded; however, up to 80% of "Other/unidentified shark" catch in the Bering Sea has been retained (4 t in the Bering Sea in both 2008 and 2009). The majority of the retained shark catch is used for fishmeal.

DATA

Data regarding sharks were obtained from the following sources:

Source	Data	Years
AKRO Catch Accounting System	Nontarget catch	2003 – 2010
Improved Pseudo Blend (AFSC)	Nontarget catch	1997 – 2002
NMFS Bottom Trawl Surveys –Eastern Bering Sea Shelf (Annual)	Biomass Index	1979 – 2010
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope (Historical)	Biomass Index	1979 – 1991
NMFS Bottom Trawl Surveys –Eastern Bering Sea Slope	Biomass Index	2002, 2004, 2008, 2010
NMFS Bottom Trawl Surveys –Aleutian Islands	Biomass Index	1980 – 2010
NMFS Longline Surveys	Catch Numbers	1989 - 2010
IPHC Longling Surveys	Catch Numbers	1997 - 2010

Incidental Catch

This report summarizes incidental shark catches by species as two data time series: 1997 – 2002 and 2003 – 2010 (Table 3). Sharks have been reported by species by the NMFS AKRO Catch Accounting System (CAS) since 2003. Prior to that shark catches by species were estimated by staff at the AFSC using a pseudo-blend method (Gaichas 2001, 2002). In reporting these catch estimates, we are assuming that shark catch aboard observed vessels is representative of shark catch aboard unobserved vessels throughout the BSAI. Observer coverage is fairly complete in the BSAI, but because observer assignment to vessels is not random, there is a possibility that the observed vessels are not representative of unobserved vessels.

From 1997 - 2010 BSAI shark catch composed from 1% to 5% of Other Species total catch (Table 3). On average Pacific sleeper shark compose 68% of the total shark catch in the BSAI, however catches have been increasingly below average since 2005 and in 2009 were only 33% of total shark catch. Other/unidentified sharks are 20% of the total shark catch on average but have also been well below average since 2007 and were only 4% of the total shark catch in 2009. The observer program reports no occurrences of "other sharks" (which could be blue sharks and brown cat sharks, among others). The observed catch of unidentified sharks appears to correlate with the catch of Pacific sleeper sharks, however this issue requires further investigation. Salmon sharks are on average 9% of the total shark catch and were 50% of the total shark catch in 2009. Spiny dogfish are 2% of the total shark catch on average and were 13% of the total shark catch in 2009.

From 1997 to 2010, spiny dogfish catch in the BSAI was rare and primarily in the Pacific cod fishery (88%, 9 t on average, Table 5), while Pacific sleeper sharks were caught primarily in the pollock fishery (36%, 108 t on average, Table 6) and the Pacific cod fishery (37%, 110 t on average). Much of the salmon shark catch occurred in the pollock fishery (89%, 41 t on average, Table 7). Other sharks and unidentified sharks occurred primarily in pollock fisheries (48%, 35 t on average, Table 8).

In the Bering Sea, the proportion of shark catch attributed to the "other/unidentified shark" category can be a large percentage of the total shark catch (Table 3). For example, in 2002 and 2006, the "other/unidentified shark" category accounted for 34% and 44%, respectively, of the total shark catch. However, there were no "other" species of sharks recorded in the observer data collected during the same period, therefore all the sharks in this category were "unidentified". From 2003 - 2009 the observed catch of unidentified shark catches were all reported from trawl or longline vessels. During that time frame, Pacific sleeper sharks composed at least 98% of the shark catch (excluding unidentified sharks) on trawl vessels and > 94% of the shark catch on longline vessels, except in 2008 and 2009. During those two years, spiny dogfish made up 45% (2008) and 86% (2009) of the shark catch on longline vessels, which also coincided with low catches of unidentified sharks in the same fleet. Observed catch trends of unidentified sharks in both longline and trawl vessels mirror catch trends in Pacific sleeper sharks and it is likely that much of the unidentified shark catch is likely composed of Pacific sleeper sharks. A possibility is that some of the unidentified sharks could be cat sharks or other less common shark species, but this is not likely because other sharks do not show up in any of the observed hauls.

Observer data was used to map the spatial distribution of catch. Data was available through the Fisheries Monitoring and Analysis Division website (http://www.afsc.noaa.gov/FMA/spatial_data.htm). Observers account for 90% of the groundfish tonnage in the BSAI. Data presented here represent non-confidential data aggregated by 100 km^2 grids from fisheries that occurred during 2006 - 2009.

Bycatch of Pacific sleeper sharks (Figure 3) within observed commercial fisheries was relatively high on the EBS shelf to approximately longitude 178°50'W, northwest of St. Matthews Island and from Unimak Pass northeast along the Alaska Peninsula. Observed Pacific sleeper shark bycatch was relatively greater in 2006 and 2007.

Observed bycatch of spiny dogfish in commercial fisheries in the Bering Sea (Figure 4) is less than Pacific sleeper shark bycatch, but the spatial distribution is similar. Spiny dogfish bycatch occurs throughout the EBS shelf, generally along the shelf break heading northwest from Unimak Pass. In addition, spiny dogfish are observed within the Aleutian Islands. As with Pacific sleeper shark, in 2006 the number of hauls with spiny dogfish catch was greater than other years including one exceptional catch area near Zhemchug canyon.

Observed bycatch of unidentified sharks within commercial fisheries in the Bering Sea (Figure 5) is generally patchy in comparison to Pacific sleeper shark and spiny dogfish with only a small number of hauls reporting unidentified sharks. However, in 2006 (similar to Pacific sleeper shark and spiny dogfish) the number of hauls and the estimated weight of unidentified sharks were exceptionally high relative to other years.

Survey Biomass Estimates

Biomass estimates are available for shark species from NMFS AFSC bottom trawl surveys conducted in the EBS slope (1979 - 1991 and 2002 - 2010; Table 9 and Table 12), Aleutian Islands (AI, 1980 – 2010, Table 10 and Table 12), the eastern Bering Sea (EBS) shelf (1979 – 2010, Table 11 and Table 12). Where available, individual species biomass trends were evaluated for the two most commonly encountered shark species (spiny dogfish and Pacific sleeper shark). Sharks in the BSAI may not be sampled well by bottom trawl surveys. In many years, surveys fail to capture a single specimen of some shark species. As a result, the estimation procedure often indicates a biomass of zero or biomass estimates with high levels of uncertainty. Spiny dogfish, for example, occur in < 1% of survey hauls for all three of the BSAI surveys. The efficiency of bottom trawl gear varies by species, and trends in these biomass estimates should be considered, at best, a relative index of abundance for shark species until more formal analyses of survey efficiencies by species can be conducted. In particular, pelagic shark species, such as salmon sharks, are encountered by the trawl gear not while it is in contact with the bottom, but rather during gear deployment or retrieval, resulting in unreliable biomass estimates since the estimates are based, in part, on the amount of time the net spends in contact with the bottom. Although Pacific sleeper sharks are demersal, they are large animals that may be able to avoid bottom trawl gear and as a result, biomass estimates may be uncertain since the gear may not efficiently capture this species. These surveys may not be informative for spiny dogfish because they are rarely caught in the surveys, but they are reported in the observer data and occur in other surveys sampling the same area (likely due to gear differences as spiny dogfish may be more susceptible to longline gear).

Analysis of the EBS slope survey biomass time series is subject to the following caveats: the slope survey was standardized in 2002 to its current gear type, survey strata, and survey design. Because the survey stratification changed in 2002, biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey (2002 – 2010). Consequently, surveys from 2002 – 2010 may be useful for estimating relative abundance of commonly encountered species, while surveys between 1979 and 1991 should only be used for identifying the relative distribution of species (Gary Walters, pers. comm.).

Pacific sleeper sharks are the most abundant catch of all shark species within BSAI surveys. Pacific sleeper sharks are most consistently caught on the annual EBS slope survey in a relatively high number of hauls catching them (at least 15 hauls each year, compared to 0 – 4 in the other surveys during the same time frame) and biomass estimates ranging from 833 t (2010) to 25,445 t (2002) (Table 9 and Figure 6). Pacific sleeper shark were also often caught in the earlier time series of that survey. Pacific sleeper sharks are also captured consistently in NMFS bottom trawl surveys of the Aleutian Islands, but biomass estimates are based on a fewer number of hauls (at most 10 in 1997) and biomass estimates are generally lower (74 t in 2010, Table 10 and Figure 7). Pacific sleeper sharks are not often caught in the annual EBS shelf survey and biomass estimates range from 734 t (2003) to 5,602 t (2002) (Table 11 and Figure 8).

Spiny dogfish and salmon shark are rarely captured in any of the NMFS bottom trawl surveys in the EBS or Aleutian Islands. Often, catches are zero, with a resultant zero biomass estimate. However, spiny dogfish were caught in one haul in 2008 in the EBS slope survey (Table 9 and Figure 6), were last caught in 2006 in the Aleutian Islands survey (Table 10 and Figure 7) and in one haul each in 2009 and 2010 in the EBS shelf survey (Table 11 and Figure 8). Salmon shark have never been caught in the EBS slope survey (Table 9).One salmon shark was caught in 2002 in the Aleutian Island survey (Table 10 and Figure 7) and one in 1988 in the EBS shelf survey (Table 11 and Figure 8).

Other Data Sources

Catch from unobserved fisheries is a concern. Work is underway to estimate the bycatch of sharks in unobserved IFQ Pacific halibut fisheries (see the report titled: "Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet" also presented at the November Plan Team meeting).

NMFS bottom trawl and longline surveys and IPHC longline research survey catches of sharks from the EBS and AI are listed in Table 13. The NMFS longline survey samples stations in the Bering Sea in even years and the Aleutian Islands in odd years. Shark catch is generally greater in the odd years associated with the Aleutian Islands , but overall shark catch is low. The IPHC samples most stations annually in the BSAI and catch consists mostly of Pacific sleeper shark.

An examination of the spatial distribution of survey catches shows that Pacific sleeper shark are consistently caught throughout the EBS shelf in the IPHC LL (during years 2006 – 2009, Figure 9) and NMFS trawl surveys (2010 only shown here, Figure 10, all three surveys) with rare scattered catches in the Aleutian Islands. The distribution of Pacific sleeper sharks spreads from Unimak Pass and follows the shelf northwest beyond the Pribilof Islands, until approximately longitude 178°40'W. The IPHC LL survey caught relatively higher numbers of sleeper sharks near Unimak Pass in 2006 and 2009. Catch of sleeper sharks in the NMFS 2010 trawl survey is highest near Unimak Pass as well.

In contrast, spiny dogfish catch is mostly distributed out the Aleutian Chain in the IPHC longline survey with highest concentrations of catch occurring near the western end of the Aleutian Chain (Figure 11). Both 2006 and 2008 saw relatively high catches (compared to 2007 and 2009) of spiny dogfish in the IPHC LL surveys. Spiny dogfish occurrences in the NMFS trawl surveys are rare. Only one spiny dogfish was caught on the Bering shelf during the 2010 trawl survey.

Weight-at-length and average length and weight values for all three shark species are presented in Table 14. Data are not available in the BSAI, here GOA data are presented as a proxy. Length-at-age models have been published for salmon sharks (Goldman and Musick, 2006) in the GOA, and for spiny dogfish in the GOA (Tribuzio and Kruse, in press). Growth models for spiny dogfish have been published for many areas around the globe. Because of the difficulty with aging Pacific sleeper sharks, growth models are not available for this species. Parameters of the von Bertalanffy growth model are presented in Table 14. While sharks are slow growing compared to teleost fish, the spiny dogfish has the slowest growth rate of any modeled shark species.

ANALYTIC APPROACH, MODEL EVALUATION, AND RESULTS

Model Structure

Sharks in the BSAI are managed under Tier 6 (harvest specifications based on average historical catch), so no stock assessment modeling is performed.

Parameters Estimated Independently

Parameters estimated independently are identified for the major shark species in the Gulf of Alaska or North Pacific (Table 15). Estimates are not available for BSAI stocks and thus GOA values are used as a proxy. An estimate of the natural mortality rate (M = 0.097) is derived for spiny dogfish in the GOA (Tribuzio and Kruse, in review). The value of M (0.097) for the GOA is similar to an estimate for British Columbia spiny dogfish (0.094) (Wood et al. 1979). A range of natural mortality estimates is derived for salmon shark in the central GOA (Goldman, 2002). A natural mortality estimate is not available for Pacific sleeper sharks. Maximum reported age for central GOA salmon shark is 30 years (Goldman and Musick 2006). Maximum age of spiny dogfish in the ENP is between 80 and 100 years (Beamish and McFarlane 1985, McFarlane and Beamish 1987). Age at first recruitment to a commercial fishery is 5 years old for central GOA salmon sharks (Goldman, 2002). Maximum age and age of first recruitment are not available for spiny dogfish or Pacific sleeper shark, however, Tribuzio et al. (2010) report the youngest dogfish encountered in fishery dependent sampling was 8 years old. Ages are not currently available for Pacific sleeper shark as this species is very difficult to age.

Parameters Estimated Conditionally

Demographic analyses have been performed for both GOA spiny dogfish (Tribuzio and Kruse, in review) and ENP salmon sharks (Goldman 2002) to estimate the rebound potential and sustainable fishing levels. Assuming an unfished population, the spiny dogfish population is increasing at a rate of 3.4% (1.2-6%, 95% confidence intervals) and salmon shark are increasing at a rate of 1.2% (-1.5-4.1%, 95% confidence intervals). Sustainable fishing levels for spiny dogfish were at $F < 0.04$ and for salmon shark $F<0.05$. In both models, fishing mortality was uniform across all selected age classes. These models do not take into account bycatch mortality from unobserved fisheries. Because of the assumptions of the model (i.e. closed populations, uniform F across all ages), results should be considered as a “best case” scenario. The assumption that shark populations are unfished is not realistic because the actual fishing mortality is > 0. However, the actual level of fishing mortality is unknown.

ABC and OFL Calculations

BSAI sharks have previously been part of the “other species” complex and have not had individual ABCs and OFLs set for the species. If sharks are broken out from that group, ABCs and OFLs will need to be set for the species complex. Sharks have been considered a Tier 6 species because they are a non-target and only limited data are available. The current Tier 6 method adopted in 2008 for sharks uses the average catch during 1997-2007 where OFL is equal to this average and ABC is 75% of OFL. The NPFMC hosted a workshop on July 8, 2010 where a number of Tier 6 alternatives were discussed. Tier 6 assessment authors were requested to present alternatives to the average catch history at the September 2010 Groundfish Plan Team meeting and based on recommendations by the Plan Team and the ensuing SSC comments, a number of alternatives for sharks were suggested. We examined Tier 6 based on average catch, maximum catch, 70th, 80th, and 90th percentile of catch history. The OFLs and ABC for these alternatives are in the following table:

		Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total sharks
OFL=avg catch	ABC	6	312	36	95	449
	OFL	8	416	48	126	598
OFL=max catch	ABC	13	629	147	351	1,140
	OFL	17	839	196	468	1,520
OFL=70th percentile	ABC	7	315	35	102	459
	OFL	9	420	47	136	612
OFL=80th percentile	ABC	8	368	35	132	543
	OFL	11	490	47	176	724
OFL=90th percentile	ABC	9	515	48	229	800
	OFL	11	687	63	305	1,067

At this time, we do not recommend taking actions to change the Tier 6 calculations that would increase the catch limits of sharks. There are two primary issues of concern here: 1) bycatch of sharks in the halibut IFQ fishery; and 2) unidentified sharks. Efforts are underway to estimate bycatch in the unobserved halibut fleet and those catch estimates could be incorporated into the next stock assessment. Unidentified sharks can be a substantial portion of the total shark catch and the composition of that species category needs to be investigated further. We recommend that the Tier 6 method be re-evaluated after unobserved bycatch has been included and after more investigations into the unidentified sharks is completed.

We recommend continuing with the current Tier 6 method for all sharks until more data is available, and we recommend that the method be reassessed again in one year. Tier 6 for BSAI shark ABC and OFL are presented both for individual species and for sharks as a complex. Incidental shark catches for the years 2003 - 2010 were provided by NMFS AKRO (Table 3). Examining the catch history from 1997 to the present shows that catches would have exceeded the recommended ABC eight out of 14 years (Figure 12). However, catches over the last four years have been declining and are the lowest catches of sharks over the entire time period.

Tier 6 calculations by species and total of all species (t) and recommendations for 2011-2012.

Species	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark	Total shark complex
Average Catch	8	416	48	126	598
ABC	6	312	36	95	449
OFL	8	416	48	126	598

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on Stock, and Fishery Effects on Ecosystem

Understanding shark species population dynamics is fundamental to describing ecosystem structure and function in the Bering Sea. Shark species are top level predators as well as scavengers and likely play an important ecological role. Studies designed to determine the ecological roles of spiny dogfish, Pacific sleeper sharks, and salmon sharks are ongoing and will be critical to determine the affect of fluctuations in shark populations on community structure in the BSAI.

<u>Spiny dogfish</u>

Previous studies have shown spiny dogfish to be opportunistic feeders (Alverson and Stansby 1963), not wholly dependent on one food source. Small dogfish are limited to consuming smaller fish and invertebrates, while the larger animals will eat a wide variety of foods (Bonham 1954). Diet changes are consistent with the changes of the species assemblages in the area by season (Laptikhovsky et al. 2001). Spiny dogfish in the northwest Atlantic can eat twice as much in summer as in winter (Jones and Geen 1977). Spiny dogfish have also been shown to prey heavily on out-migrating salmon smolts (Beamish et al. 1992). In the GOA, preliminary diet studies further suggest that spiny dogfish are highly generalized, opportunistic feeders (Tribuzio, unpublished data).

<u>Pacific sleeper shark</u>

Pacific sleeper sharks were once thought to be sluggish and benthic because their stomachs commonly contain offal, cephalopods, and bottom dwelling fish such as flounder (*Pleuronectidae*) (e.g., Yang and Page 1999). The more current hypothesis is that these sharks make vertical oscillations throughout the water column searching for prey as well as scavenging. Evidence for this behavior was documented in a tagging study in the Gulf of Alaska (Hulbert et al. 2006). Also, a diet analysis documented prey from different depths in the stomachs of a single shark, such as giant grenadier (*Albatrossia pectoralis*) and pink salmon (*Oncorhynchus gorbuscha*), indicating that they make depth oscillations in search of food (Orlov and Moiseev 1999). Other diet studies that have found that Pacific sleeper sharks prey on fast moving fish such as salmon (*O. spp.)* and tuna (*Thunnus spp*.), and marine mammals such as harbor seals (*Phoca vitulina*), that live near the surface (e.g., Bright 1959; Ebert et al. 1987; Crovetto et al. 1992; Sigler et al. 2006), suggesting that these sharks may not be as sluggish and benthic oriented as once thought. Although Pacific sleeper sharks share the same areas as pupping Stellar sea lions (*Eumetopias jubatus*) in the Gulf of Alaska, they were not found to prey on newborn sea lions but did have tissues from other marine mammals in their stomachs (Sigler et al. 2006). Taggart et al. (2005) found that Pacific sleeper sharks in Glacier Bay were only caught in traps at locations where harbor seals were at their highest concentrations. However, they did not find any seal tissue in their stomachs and concluded that Pacific sleeper sharks may either be a predator of the seals or might be attracted to the same food sources as the seals, such as walleye pollock (*Theragra chalcogramma*), cephalopods, flounder, or capelin (*Mallotus villosus*).

Analyses of mercury and other elemental concentrations in the tissues of Pacific sleeper sharks show that they are at a lower trophic level than ringed seals (*Pusa hispida*) and were at a similar level as flathead sole (*Hippoglossoides elassodon*) (McMeans et al. 2007). Another study used stable isotopes to determine the trophic level of Greenland sharks and found that larger sharks were at a higher trophic level than smaller sharks because larger sharks were more likely to feed on marine mammals (Fisk et al. 2002).

Salmon Shark

Salmon sharks are opportunistic feeders, sharing the highest trophic level of the food web in subarctic Pacific waters with marine mammals and seabirds (Brodeur 1988, Nagasawa 1998, Goldman and Human 2004). They feed on a wide variety of prey, including salmon (*Oncorhynchus* sp.), rockfishes (family Sebastes), sablefish (*Anoplopoma fimbria*), lancetfish (family Alepisaurus), daggertooth (family Anotopterus), lumpfishes (family Cyclopteridae), sculpins (family Cottidae), Atka mackerel (*Pleurogrammus*), mackerel (family Scomber), pollock and tomcod (family Gadidae), herring (family Clupeidae), spiny dogfish, tanner crab (family Chionoecetes), squid, and shrimp (Sano 1960 and 1962, Farquhar 1963, Hart 1973, Urquhart 1981, Compagno 1984 and 2001, Nagasawa 1998). Incidental catch in the central Pacific has been significantly reduced since the elimination of the drift gillnet fishery, and the population appears to have rebounded to its former levels (Yatsu et al. 1993, H. Nakano pers. comm.). Additionally, recent demographic analyses support the contention that salmon shark populations in the eastern and western North Pacific are stable at this time (Goldman 2002). Seasonal foraging movements and migratory patterns of salmon sharks in the northeast Pacific Ocean have been described in Hulbert et al. (2005) and Weng et al. (2005).

Ecosystem effects on *GOA Sharks*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys, changes mean wt-at-age	Stable, data limited	Unknown
Non-pandalid shrimp and other benthic organism	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Composes the main portion of spiny dogfish diet	Unknown
Sandlance, capelin, other forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Salmon	Populations are stable or slightly decreasing in some areas	Small portion of spiny dogfish diet, maybe a large portion of salmon shark diet	No concern
Flatfish	Increasing to steady populations currently at high biomass levels	Adequate forage available	No concern
Pollock	High population levels in early 1980's, declined to stable low level at present	Primarily a component of salmon shark diets	No concern
Other Groundfish	Stable to low populations	Varied in diets of sharks	No concern
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Not likely a predator on sharks	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	No concern
Fish (Pollock, Pacific cod, halibut)	Stable to increasing	Possible increases to juvenile spiny dogfish mortality	
Sharks	Stable to increasing	Larger species may prey on spiny dogfish	Currently, no concern
Changes in habitat quality			
Temperature regime	Warm and cold regimes	May shift distribution, species tolerate wide range of temps	No concern
Benthic ranging from inshore waters to shelf break and down slope	Sharks can be highly mobile, and benthic habitats have not been monitored historically, species may be able to move to preferred habitat, no critical habitat defined for GOA	Habitat changes may shift distribution	No concern

GOA Sharks **effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Not Targeted	None	No concern	No concern
Fishery concentration in space and time	None	No concern	No concern
Fishery effects on amount of large size target fish	If targeted, could reduce avg size of females, reduce recruitment, reduce fecundity, skewed sex ratio (observed in areas targeting species)	No concern at this time	No concern at this time
Fishery contribution to discards and offal production	None	No concern	No concern
Fishery effects on age-at-maturity and fecundity	Age at maturity and fecundity decrease in areas that have targeted species	No concern at this time	No concern at this time

Data Gaps and Research Priorities

Data limitations are severe for shark species in the BSAI and effective management of sharks is extremely difficult with the current limited information. Gaps include inadequate catch estimation, unreliable biomass estimates, lack of size frequency collections, and a lack of life history information including age and maturity, especially for Pacific sleeper sharks. Regardless of future management decisions regarding the structure of the Other Species management category, it is essential to continue to improve shark fishery and survey sampling with the collection of biological data from sharks. Future shark research priorities will focus on the following areas:

1. Expand collection of length data and begin collecting age samples from NMFS and IPHC surveys in the BSAI
    a. Actions: Began collecting lengths of spiny dogfish in the NMFS longline survey
2. Improve species identification by observers
3. Collect length data from sharks caught on observed commercial vessels
    a. Actions: Instituted observer special projects to record lengths on sharks for 2011
4. Estimate bycatch from unobserved fisheries
    a. Actions: Working group formed to estimate bycatch in unobserved halibut fleet for all non-target species. See ”Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet” document
5. Define the stock structure and migration patterns (i.e. tagging studies, genetics)
    a. Actions: Recovered tags from first year of pop-off archival study, data still being analyzed. Deployed more tags in 2010.
6. Determine or clarify existing estimates of life history parameters for use in models
    a. Actions: Pilot study underway to examine improved aging methods for spiny dogfish and to examine methods to age Pacific sleeper sharks

SUMMARY

There is no evidence to suggest that overfishing is occurring for any shark species in the BSAI, because catch limits of the Other Species complex were not exceeded and overfishing limits had not previously been set for sharks. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI, and most incidentally captured sharks are not retained. Incidental catches of shark species in the BSAI fisheries have been very small compared to catches of target species. Sharks have only been reported to species in the catch since 1997 and have made up from 1% to 5% of Other Species catch from 1997 – 2010. Preliminary comparisons of incidental catch rates with available biomass by species suggest that current levels of incidental catches are low relative to available biomass

for Pacific sleeper sharks in the BSAI. In the BSAI, average catch of Pacific sleeper sharks from 1997 – 2007 (416 t) represented 3.6% of the average available Pacific sleeper shark biomass from BSAI bottom trawl surveys (total of average Pacific sleeper shark biomass from EBS slope, AI slope, and EBS shelf surveys for the years 1996 – 2010 is 11,549 t; Table 9 - Table 11). Spiny dogfish and salmon sharks were rarely encountered in commercial fisheries or bottom trawl surveys in the BSAI.

2011 and 2012 recommendations	Spiny Dogfish	Pacific Sleeper Shark	Salmon Shark	Other/unid Shark
Tier	6	6	6	6
M	0.097	unk	0.18	unk
Avg catch (1997-2007)	8	416	48	126
ABC	6	312	36	95
OFL	8	416	48	126

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Table 1. Biological characteristics and depth ranges for shark species in the eastern Bering Sea, and Aleutian Islands (BSAI). Missing information is denoted by "?".

Scientific Name	Common Name	Max. Obs. Length (TL, cm)	Max. Obs. Age	Age, Length, 50% Maturity	Feeding Mode	Fecundity	Depth Range (m)
Apristurus brunneus	brown cat shark	68[1]	?	?	Benthic[3]	?	1,306[2]
Carcharodon carcharias	White shark	792[4]	36[7]	15 yrs, 5 m[7]	Predator[6]	7-14[5]	1,280[3]
Cetorhinus maximus	basking shark	1,520[1]	?	5 yrs, 5m[8]	Plankton[6]	?	?
Hexanchus griseus	sixgill shark	482[9]	?	4m[1]	Predator[6]	22-108[1]	2,500[10]
Lamna ditropis	salmon shark	305[1]	20[11]	6-9 yrs, 165 cm PCL[11]	Predator[6]	3-5[7]	668[12]
Prionace glauca	blue shark	400[16]	15[13]	5 yrs[5], 221 cm[14]	Predator[6]	15-30 (up to 130)[15]	150[16]
Somniosus pacificus	Pacific sleeper shark	700[1]	?	?	Benth/Scav[17]	Up to 300[1]	2,700[18]
Squalus suckleyi	Spiny dogfish	125[19]	107[20]	34 yrs, 80 cm[19]	Pred/Scav/Bent[19]	7-14[19]	300[3]

[1]Compagno, 1984; [2]Eschmeyer et al., 1983; [3]Mecklenburg et al. 2002; [4]Scott and Scott, 1988; [5]Smith et al. 1998; [6]Cortes, 1999; [7]Gilmore, 1993; [8]Mooney-Seus and Stone, 1997; [9]Castro, 1983; [10]Last and Stevens, 1994; [11]Goldman and Musick 2006, [12]Hulbert et al. 2005; [13]Stevens, 1975; [14] ICES 1997; [15] White et al. 2006; [16]Smith, 1997; [17]Yang and Page, 1999; [18]www.nurp.noaa.gov; [19]Tribuzio ongoing studies; [20]G. A. McFarlane, pers. comm.

Table 2. Time series of Other Species TAC, Other Species and shark catch, ABC for sharks and the management method for 1997-2010.

Year	Other spp. TAC	Est. other spp. catch	Est. shark catch	ABC	Management method
1997	25,800	25,176	368	N/A	Other Species TAC
1998	28,800	25,531	497	N/A	Other Species TAC
1999	32,860	20,562	530	N/A	Other Species TAC
2000	31,360	26,108	590	N/A	Other Species TAC
2001	26,500	27,178	764	N/A	Other Species TAC
2002	30,825	26,296	1,362	N/A	Other Species TAC
2003	32,309	27,010	520	N/A	Other Species TAC
2004	27,205	30,492	515	N/A	Other Species TAC
2005	29,000	30,761	417	N/A	Other Species TAC
2006	29,000	28,525	689	N/A	Other Species TAC
2007	37,355	27,837	331	463	Other Species TAC
2008	50,000	31,172	185	463	Other Species TAC
2009	50,000	28,352	144	447	Other Species TAC
2010	50,000	19,796	40	449	Other Species TAC

Data Sources: TAC and Other Species catch came from AKRO catch statistics website. 1977- 2002 Gaichas (2002); 2003 - 2009 NMFS AKRO BLEND database, Juneau, AK 99801, as of Oct. 10, 2010.

Table 3. Estimated incidental catch (t) of sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by species as of October 10, 2010. 1997 – 2002 from the NMFS pseudo-blend catch estimation procedure (Gaichas 2001, 2002), 2003 – 2010 from NMFS AKRO blend-estimated annual catches.

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/ Unidentified shark	Total sharks	Total other species	Shark % of other species
1997	4	304	7	53	368	25,176	1%
1998	6	336	18	136	497	25,531	2%
1999	5	319	30	176	530	20,562	3%
2000	9	490	23	68	590	26,108	2%
2001	17	687	24	35	764	27,178	3%
2002	9	839	47	468	1,362	26,296	5%
2003	11	280	196	33	520	27,010	2%
2004	9	420	26	60	515	30,492	2%
2005	11	333	47	26	417	30,761	1%
2006	7	313	63	305	689	28,525	2%
2007	3	256	44	28	331	27,837	1%
2008	17	120	42	7	185	31,172	1%
2009	19	47	72	6	144	28,352	1%
2010	8	17	11	4	40	19,796	0%
Total est. catch	135	4,761	651	1,405	6,953	374,796	
species % of total sharks	2%	68%	9%	20%			
Avg. 1997 – 2007	8	416	48	126	598	27,221	

Table 4. Estimated discard rates of sharks (by species) in the BSAI. Source: AKFIN database, Oct 21, 2010. Years and species without available data are blank and years and species with zero catches are marked "NA".

Year	Spiny dogfish	Pacific sleeper shark	Salmon shark	Other/Unidentified shark
	Aleutian Islands			
1999				
2000		100%	NA	
2001				
2002	NA	NA		
2003	NA	100%	NA	NA
2004	NA	100%		NA
2005	NA	100%	100%	
2006	100%	NA	NA	
2007	NA	100%	NA	
2008	100%	100%		
2009	100%	NA	NA	NA
2010	100%	100%	NA	
Average	100%	100%	100%	
	Bering Sea			
1999	NA	97%	100%	100%
2000	NA	95%	91%	NA
2001	100%	97%	82%	100%
2002	NA	86%	94%	100%
2003	91%	78%	98%	88%
2004	100%	98%	96%	97%
2005	100%	96%	93%	73%
2006	100%	95%	97%	97%
2007	100%	94%	98%	54%
2008	100%	95%	98%	20%
2009	100%	95%	99%	20%
2010	100%	86%	100%	33%
Average	99%	93%	95%	71%

Table 5. Estimated catches (t) of spiny dogfish in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2010 are from NMFS AKRO blend-estimated annual catches.

Year	Atka Mackerel	Flatfish	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0	0	4.1	0	0	0	0		4.1
1998	0.2	0.4	5.6	0.1	0	0	0		6.3
1999	0	0	4.9	0	0	0	0		4.9
2000	0	0.2	8.6	0	0	0	0		8.8
2001	2.8	1.6	12.7	0.1	0	0.1	0		17.3
2002									
2003	0.1	0	11.0	0	0	0	0	0.1	11.3
2004	0	0.2	8.3	0	0	0.1	0	0	8.6
2005	0	0.1	11.2	0	0	0	0	0	11.4
2006	0.1	0.1	6.6	0.2	0	0.1	0	0	7.0
2007	0	0.3	2.5	0.2	0	0.1	0	0	3.0
2008	0.1	0.2	10.2	0.2	0.2	0	0	5.9	16.7
2009	0	0.1	18.2	0.4	0	0.2	0	0	18.9
2010	0	0.5	7.1	0.3	0	0	0	0	7.9
Total	3.4	3.6	111.1	1.5	0.1	0.6	0.1	5.9	126.3
Avg. % of Total	3%	3%	88%	1%	0%	0%	0%	5%	

Table 6. Estimated catches (t) of Pacific sleeper sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2010 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish Total	Pacific Cod Total	Pollock Total	Rockfish Total	Sablefish Total	Turbot Total	Halibut	Total
1997	0.1	0.9	74.8	105.2	0.9	45.3	77	0	304.2
1998	0	0.9	146.7	74.4	0	0	113.5	0	335.5
1999	2.4	39.4	103.3	76.8	3	15.1	78.2	0	318.2
2000	0.3	42	114.7	103.8	2.7	143.7	83.2	0	490.4
2001	27.8	179.6	252.7	205.7	0	1.8	19.3	0	686.9
2002									
2003	0.5	33.5	121.0	74.4	0.5	19.3	9.7	18.4	277.4
2004	2.0	37.3	229.8	144.0	0.7	2.3	2.7	1.1	419.9
2005	0.0	6.3	191.2	127.6	0.1	3.8	2.7	0.1	331.8
2006	0.0	9.5	123.1	178.0	0.1	1.0	1.3	0.1	313.0
2007	1.1	8.4	44.3	180.2	14.5	2.4	0.5	0.0	251.5
2008	0.1	5.9	12.3	98.2	1.2	1.2	0.4	0.0	119.3
2009	0.6	8.2	11.1	24.4	0.6	1.9	0.1	0.0	46.9
2010	0.0	0.9	4.2	10.5	0.1	0.8	0.1	0.0	16.6
Total	34.8	372.8	1,429.3	1,403.2	24.4	238.7	388.5	19.8	3,911.6
Avg. % of Total	1%	10%	37%	36%	1%	6%	10%	1%	

Table 7. Estimated catches (t) of salmon sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2010 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0.1	0	0	6.7	0	0	0		6.8
1998	0	0.1	0.8	16.2	0	0	0.8		17.9
1999	0.2	2.5	1.2	24.7	0	0	1.5		30.1
2000	0	0	3.8	19.5	0	0	0		23.3
2001	0.4	0.4	1.2	22.5	0	0	0		24.5
2002									
2003	0.1	0.5	0.9	194.9	0	0	0	0	196.3
2004	0	0.1	0.1	25.5	0	0	0	0	25.6
2005	18.2	0.7	2.0	25.7	0	0	0	0	46.7
2006	0.2	25.9	1.2	36.2	0	0	0	0	63.3
2007	0.1	0	0	44.4	0	0	0	0	44.5
2008	0	0.8	0	41.7	0	0	0	0	42.5
2009	0.3	1.7	0.1	69.6	0	0	0	0	75.6
2010	0.1	0.4	0	10.7	0	0	0	0	
Total	19.7	32.9	11.2	538.2	0	0	2.3	0	597.1
Avg. % of Total	3%	5%	2%	89%	0%	0%	0%	0%	

Table 8. Estimated catches (t) of other and unidentified sharks in the eastern Bering Sea and Aleutian Islands (BSAI) by target fishery. Years 1997-2001 from the pseudo-blend catch estimation procedure (Gaichas 2002), 2004-2010 are from NMFS AKRO CAS.

Year	Atka Mackerel	Flatfish	Pacific Cod	Pollock	Rockfish	Sablefish	Turbot	Halibut	Total
1997	0	0.4	26.8	15.6	2.5	1.2	6.3		52.8
1998	13.1	0	48.4	45.4	0	2.1	26.9		135.9
1999	0	0.2	18.8	10.3	0	1.8	144.9		176
2000	0	1.2	56.1	0.1	0	7.2	3		67.6
2001	0	0	19.6	2.3	0	10.4	2.7		35
2002									
2003	0	0	19.7	11.9	0	0	1.3	0	32.9
2004	0	22.2	20.2	17.6	0	0	0	0	60.1
2005	0	0	10.1	16.0	0	0	0	0	26.2
2006	0	2.1	3.6	298.0	0	0.1	1.6	0	305.4
2007	0	5.9	2.1	19.8	0	0	0	0	27.8
2008	0	0.3	0.6	5.9	0	0	0	0	6.8
2009	0	0	0.3	5.5	0.2	0	0	0	6.0
2010	0	0	0.3	4.0	0	0	0	1	5.3
Total	13.1	32.3	226.7	452.4	2.7	22.8	186.7	1	937.8
Avg. % of Total	1%	3%	24%	48%	0%	2%	20%	0%	

Table 9. Eastern Bering Sea slope AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls (Jerry Hoff, pers. comm., October, 2010).

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	105	0			0			0		
1981	205	1	1	0.83	0			0		
1982	299	3	8	0.73	1	12	1.02	0		
1985	325	3	2	0.66	19	543	0.1	0		
1988	131	0			10	1,993	0.39	0		
1991	85	0			6	1,235	0.44	0		
New Slope Survey										
2002	141	0			15	25,445	0.87	0		
2004	231	0			24	2,260	0.34	0		
2008	207	1	14	1	28	2,037	0.27	0		
2010	200	0			19	833	0.27	0		

Table 10. Aleutian Islands AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV, and number of hauls. Source: Personal communication, Mark Wilkins, Oct. 2010.

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1980	129	0			0			0		
1983	372	3	2	0.61	3	254	0.65	0		
1986	443	6	14	0.51	12	1,995	0.36	0		
1991	331	0			3	2,927	0.69	0		
1994	381	9	47	0.37	3	374	0.64	0		
1997	397	2	11	0.71	10	2,486	0.29	0		
2000	419	3	25	0.62	3	2,638	0.57	0		
2002	417	0			4	536	0.55	1	893	1.00
2004	420	0			2	1,017	0.96	0		
2006	358	6	62	0.49	1	76	1.00	0		
2010	418	0	0	0	1	74	1.00	0	0	0

Table 11. Eastern Bering Sea shelf AFSC trawl survey estimates of individual shark species total biomass (metric tons) with CV and number of hauls (Bob Lauth, pers. comm., October, 2010).

		Spiny Dogfish			Pacific sleeper Shark			Salmon Shark		
Year	Survey Hauls	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV	Hauls w/catch	Biomass Est.	CV
1979	452	4	389	0.56	0			0		
1980	342	0			0			0		
1981	290	0			0			0		
1982	329	0			0			0		
1983	354	2	379	0.83	0			0		
1984	355	0			0			0		
1985	353	1	47	0.99	0			0		
1986	354	0			0			0		
1987	342	3	223	0.60	0			0		
1988	353	1	249	1.0	0			1	3,808	1.0
1989	353	0			0			0		
1990	352	0			0			0		
1991	351	0			0			0		
1992	336	0			2	2,564	0.72	0		
1993	355	0			0			0		
1994	355	0			2	5,012	0.82	0		
1995	356	0			1	1,005	1.00	0		
1996	355	0			2	2,804	0.82	0		
1997	356	1	37	1	0			0		
1998	355	1	254	1	1	2,124	1.00	0		
1999	353	0			2	2,079	0.71	0		
2000	352	0			1	1,487	1.00	0		
2001	355	0			0			0		
2002	355	0			3	5,602	0.65	0		
2003	356	0			1	734	1.00	0		
2004	355	1	28	1.00	2	3,093	0.71	0		
2005	353	0			2	1,532	0.75	0		
2006	356	0			2	2,944	0.78	0		
2007	356	0			0			0		
2008	375	0			0			0		
2009	376	1	72	1	0			0		
2010	376	1	89	1.00	4	5,299	0.53	0		

Table 12. Total shark biomass estimates (t) from AFSC bottom trawl surveys in the eastern Bering Sea (EBS), and Aleutian Islands (AI).

Year	EBS Shelf	EBS Slope	AI
1979	389	0	
1980	0		0
1981	0	1	
1982	0	20	
1983	379		255
1984	0		
1985	47	545	
1986	0		2,009
1987	223		
1988	4,057	1,993	
1989	0		
1990	0		
1991	0	1,235	2,926
1992	2,564		
1993	0		
1994	5,012		420
1995	1,005		
1996	2,804		
1997	37		2,497
1998	2,378		
1999	2,079		
2000	1,487	Pilot survey	2,663
2001	0		
2002	5,602	25,445	1,429
2003	734		
2004	3,121	2,260	1,017
2005	1,523		
2006	2,944		138
2007	0		
2008	0	2,051	
2009	71		
2010	5,388	833	74

Source: Gaichas et al. (1999, Table 15), Gaichas (2003, Table 16-8). EBS Shelf and Slope updated Oct, 2010 (Pers. Comm., Bob Lauth, Jerry Hoff). AI updated Oct 2010 (Pers. Comm., Mark Wilkins).

Table 13. Research catches of sharks between 1977 and 2010 in the eastern Bering Sea (EBS), and Aleutian Islands (AI). Trawl survey catches are reported in metric tons (t). The GOA LL and IPHC LL survey catches are provided in numbers. IPHC Survey data is delayed by one year, thus 2010 survey data will not be included until the 2011 SAFE. Also, the total catch numbers from the IPHC survey are estimated based on the subsample of observed hooks.

	NMFS Trawl Surveys		NMFS LL	IPHC LL
Year	EBS (t)	AI (t)	EBS and AI (#'s)	EBS and AI (#'s)
1977	0			
1978				
1979	0.03			
1980	0	0.3		
1981	0.07			
1982	0.16	0.02		
1983	0.01	0.26		
1984				
1985	0.59			
1986		2.21		
1987	0.01			
1988	1.06			
1989	0.07			
1990	0			
1991	0.56	0.52		
1992	0.09			
1993				
1994	0.17	0.13		
1995	0.04			
1996	0.1		2	
1997	0.11	0.42	81	
1998	0.09		1	207
1999	0.08		20	152
2000	8.5	0.62	2	723
2001			12	164
2002	5.74	0.23	1	169
2003	0.03		11	368
2004	0.76	0.1	3	251
2005	0		6	237
2006	0	0.07	2	241
2007	0		34	170
2008	0.47		8	208
2009	2.02		2	234
2010	0.42		0	

Sources: Gaichas et al. (1999, Table 3), Gaichas (2002, Table 15-9), Bob Lauth, Mark Wilkins and Jerry Hoff (Pers. Comm. 2010)

Table 14. Life history parameters for spiny dogfish, Pacific sleeper, and salmon sharks. Top: Length-weight coefficients and average lengths and weights are provided for the formula $W=aL^b$, where W = weight in kilograms and L = PCL (precaudal length in cm). Bottom: Length at age coefficients from the von Bertalanffy growth model, where L_∞ is PCL or the TL_{ext} (total length with the upper lobe of the caudal fin depressed to align with the horizontal axis of the body). Sources: NMFS sablefish longline surveys 2004 - 2006, NMFS GOA bottom trawl surveys in 2005; Sigler et al (2006); Goldman and Musick (2006); and Tribuzio and Kruse (in review).

Species	Area	Gear type	Sex	Average size PCL (cm)	Average weight (kg)	a	b	Sample size
Spiny dogfish	GOA	NMFS bottom trawl surveys	M	63.4	2	1.40E-05	2.86	92
Spiny dogfish	GOA	NMFS bottom trawl surveys	F	63.8	2.29	8.03E-06	3.02	140
Spiny dogfish	GOA	Longline surveys	M	64.6	1.99	9.85E-06	2.93	156
Spiny dogfish	GOA	Longline surveys	F	64.7	2.2	3.52E-06	3.2	188
Pacific sleeper shark	Central GOA	Longline surveys	M	166	69.7	2.18E-05	2.93	NA
Pacific sleeper shark	Central GOA	Longline surveys	F	170	74.8	2.18E-05	2.93	NA
Salmon shark	Central GOA	NA	M	171.9	116.7	3.20E-06	3.383	NA
Salmon shark	Central GOA	NA	F	184.7	146.9	8.20E-05	2.759	NA

Species	Sex	L_∞ (cm)	κ	t_0 (years)
Spiny Dogfish	M	93.7 (TL_{ext})	0.06	-5.1
Spiny Dogfish	F	132.0 (TL_{ext})	0.03	-6.4
Pacific Sleeper Shark	M	NA	NA	NA
Pacific Sleeper Shark	F	NA	NA	NA
Salmon Shark	M	182.8 (PCL)	0.23	-2.3
Salmon Shark	F	207.4 (PCL)	0.17	-1.9

Table 15. Natural mortality parameter estimates for each species in the GOA. Sources for GOA spiny dogfish are Tribuzio and Kruse (in review), ENP spiny dogfish (Wood et al. 1979) and Goldman (2002) for salmon shark.

Species	Area	M for Tier calc	Max age	Age of first recruit
Spiny dogfish	GOA	0.097	NA	NA
Spiny dogfish	ENP	0.094	80 – 100	NA
Pacific sleeper shark	NA	NA	NA	NA
Salmon shark	GOA	0.18	30	5

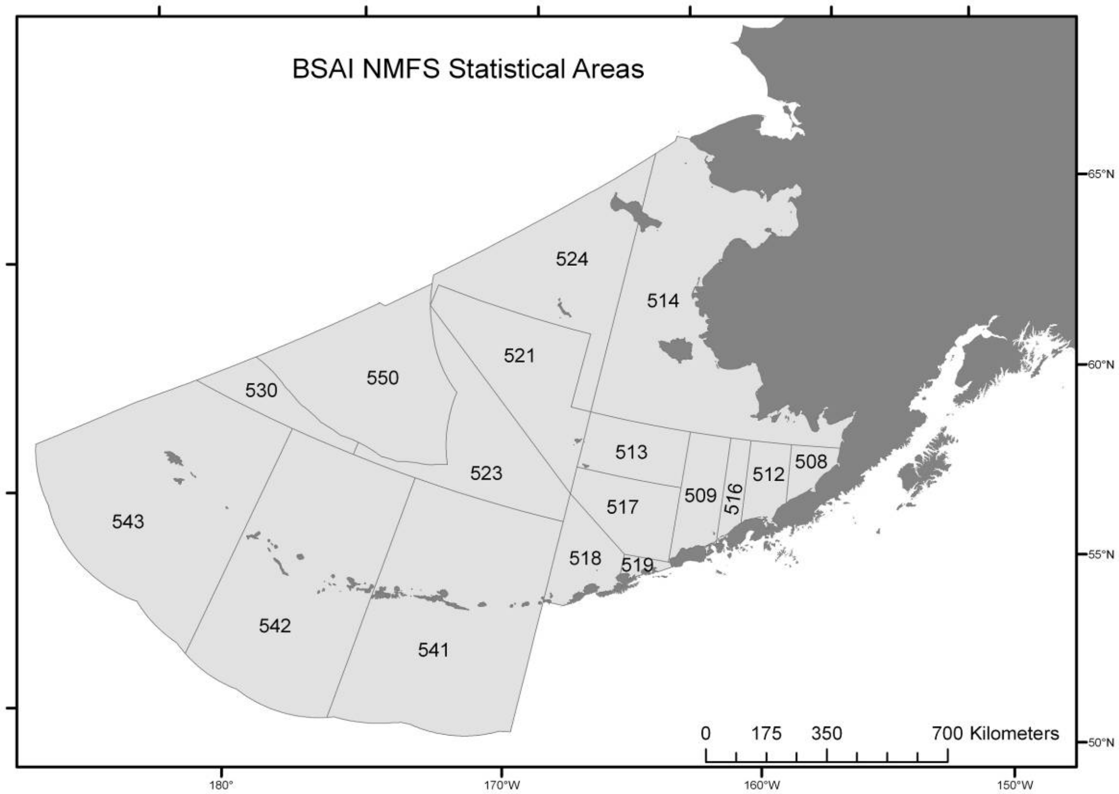

Figure 1. NMFS statistical areas in the Bering Sea and Aleutian Islands.

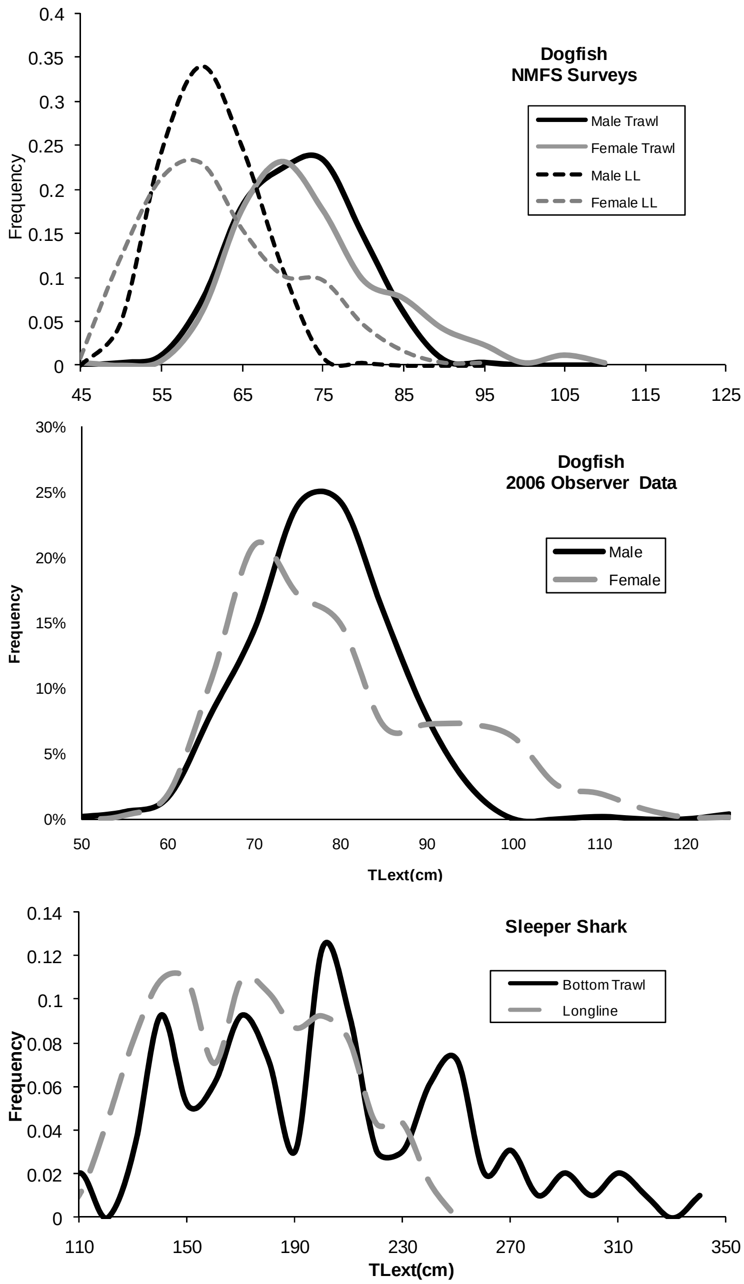

Figure 2. Observed length frequencies for spiny dogfish from (top) the most recent NMFS trawl and longline surveys, and (center) for a special project with the observer program in 2006 and for Pacific sleeper shark (bottom) from all years of the NMFS trawl survey and a targeted longline survey in 2001 near Kodiak Island.

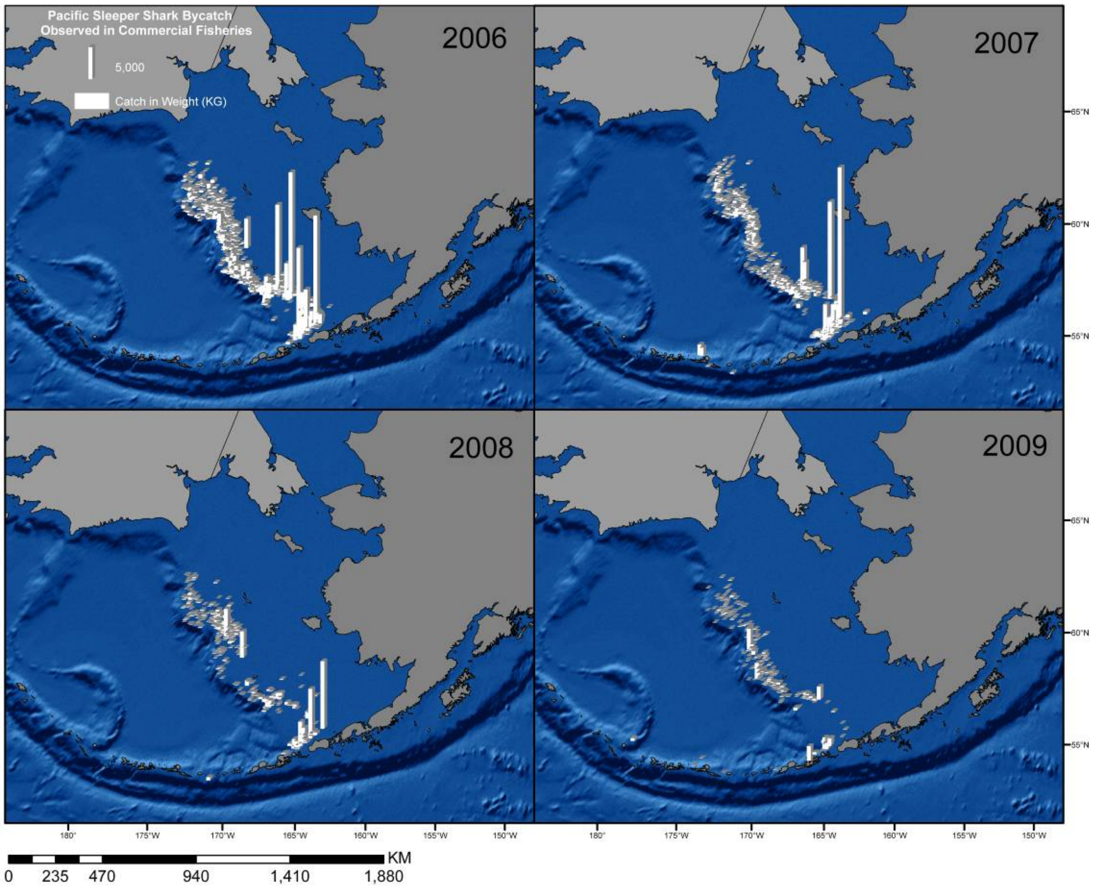

Figure 3. Spatial distribution of observed Pacific sleeper shark catch in the BSAI from 2006 - 2009. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 100km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 15, 2010 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

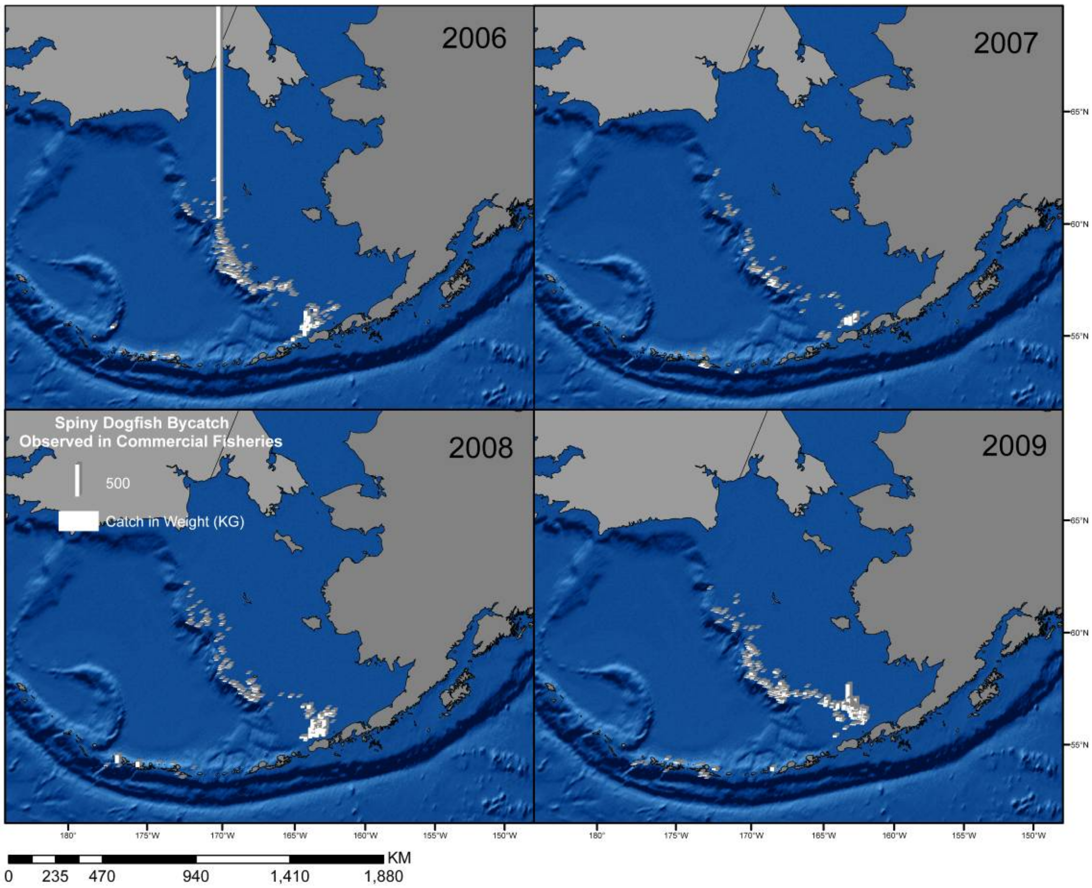

Figure 4. Spatial distribution of observed spiny dogfish catch in the BSAI from 2006 - 2009. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 100km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 15, 2010 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

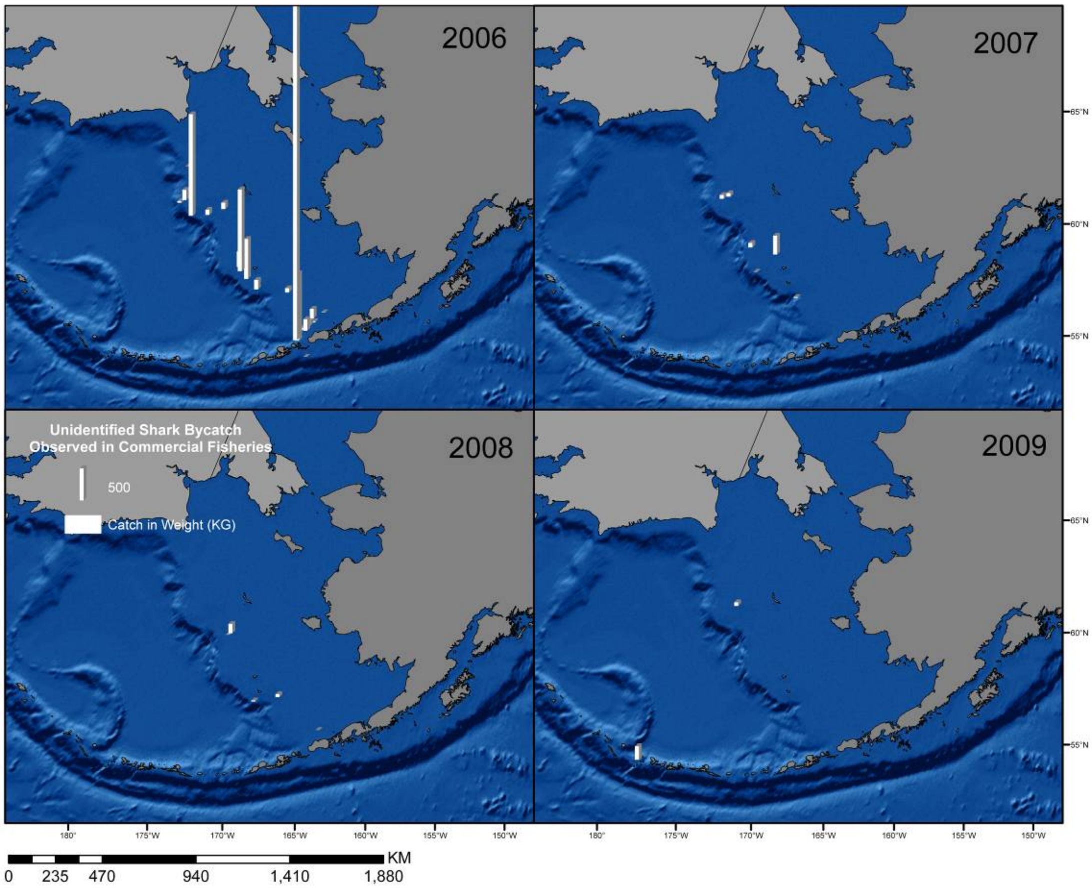

Figure 5. Spatial distribution of observed unidentified shark catch in the BSAI from 2006 - 2009. Height of the bar represents the catch in kilograms. Each bar represents non-confidential catch data summarized into 100km^2 grids. Grid blocks with zero catch were not included for clarity. Data provided by the Fisheries Monitoring and Analysis division website, queried October 15, 2010 (http://www.afsc.noaa.gov/FMA/spatial_data.htm).

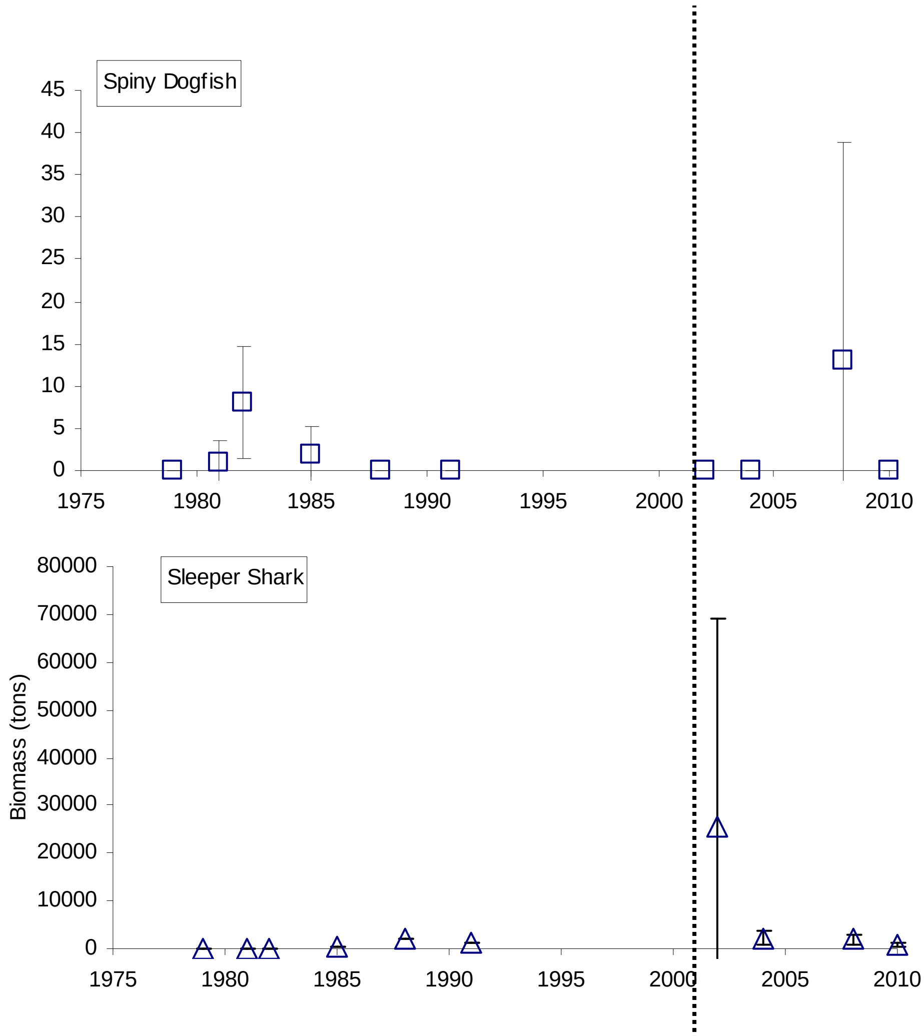

Figure 6. Time series of biomass estimates (t) in the eastern Bering Sea (EBS) slope AFSC bottom trawl surveys of spiny dogfish and Pacific sleeper sharks (salmon sharks are not encountered on the EBS slope survey), reported here as an index of relative abundance. Error bars are 95% confidence intervals. Dashed line indicates beginning of new EBS slope survey (2002, 2004), which is not comparable to the historical survey (1979 – 1991). Analysis of EBS slope survey biomass trends is subject the following time series caveats. The slope survey was standardized in 2002 to its current gear type, survey strata, and survey design. Because the survey stratification changed in 2002, biomass estimates are not comparable between the historical EBS slope survey (1979 – 1991) and the new slope survey biomass (2002 and 2008). In addition, prior to 2002, the survey utilized a mix of commercial and research vessels with various gear configurations. Salmon shark have not been recorded on this survey.

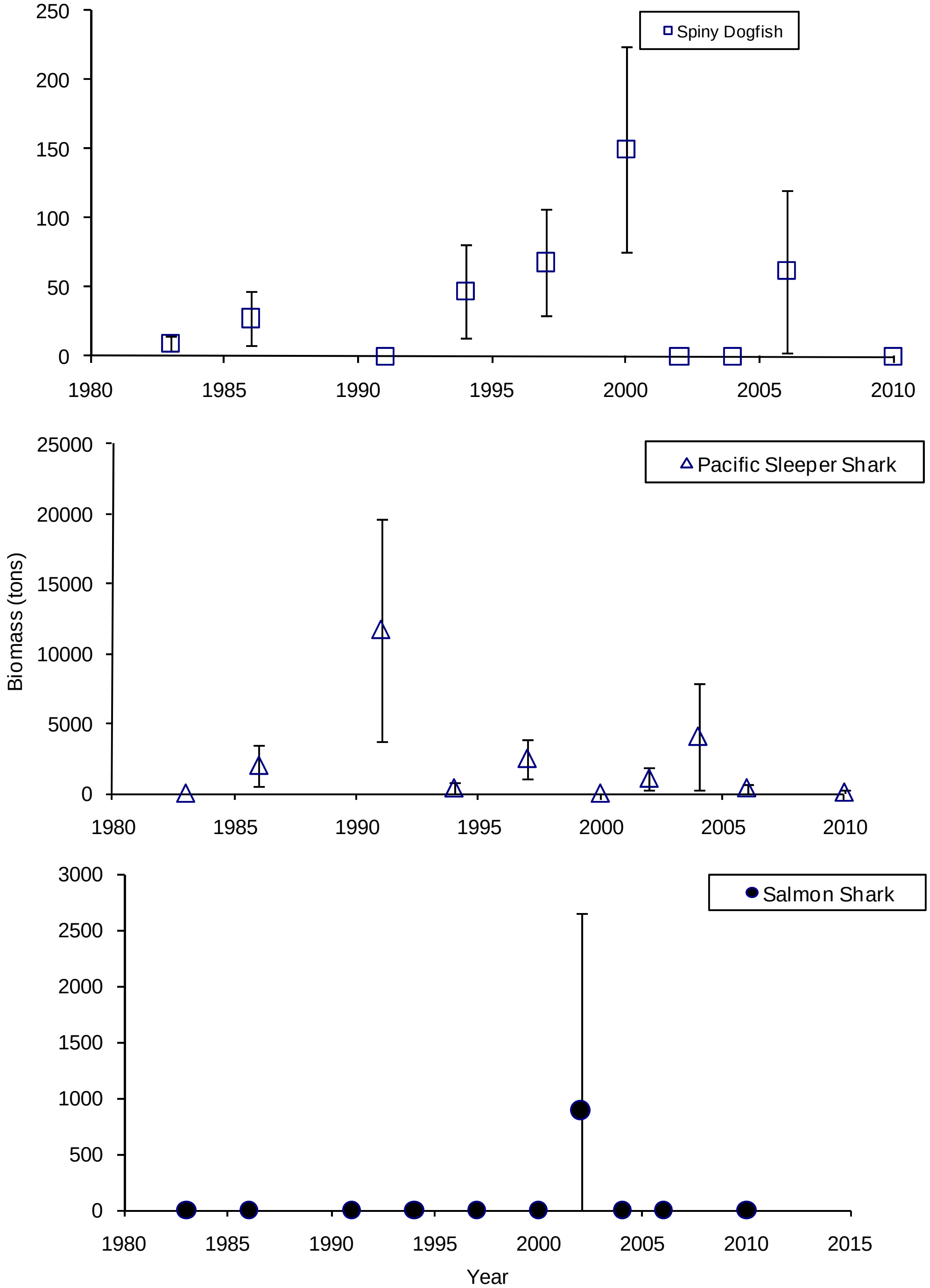

Figure 7. Time series of biomass estimates (t) for spiny dogfish, Pacific sleeper and salmon sharks in the Aleutian Islands (AI) AFSC bottom trawl surveys, reported here as an index of relative abundance. Error bars are 95% confidence intervals. Catchability of sharks in the AI trawl survey is unknown.

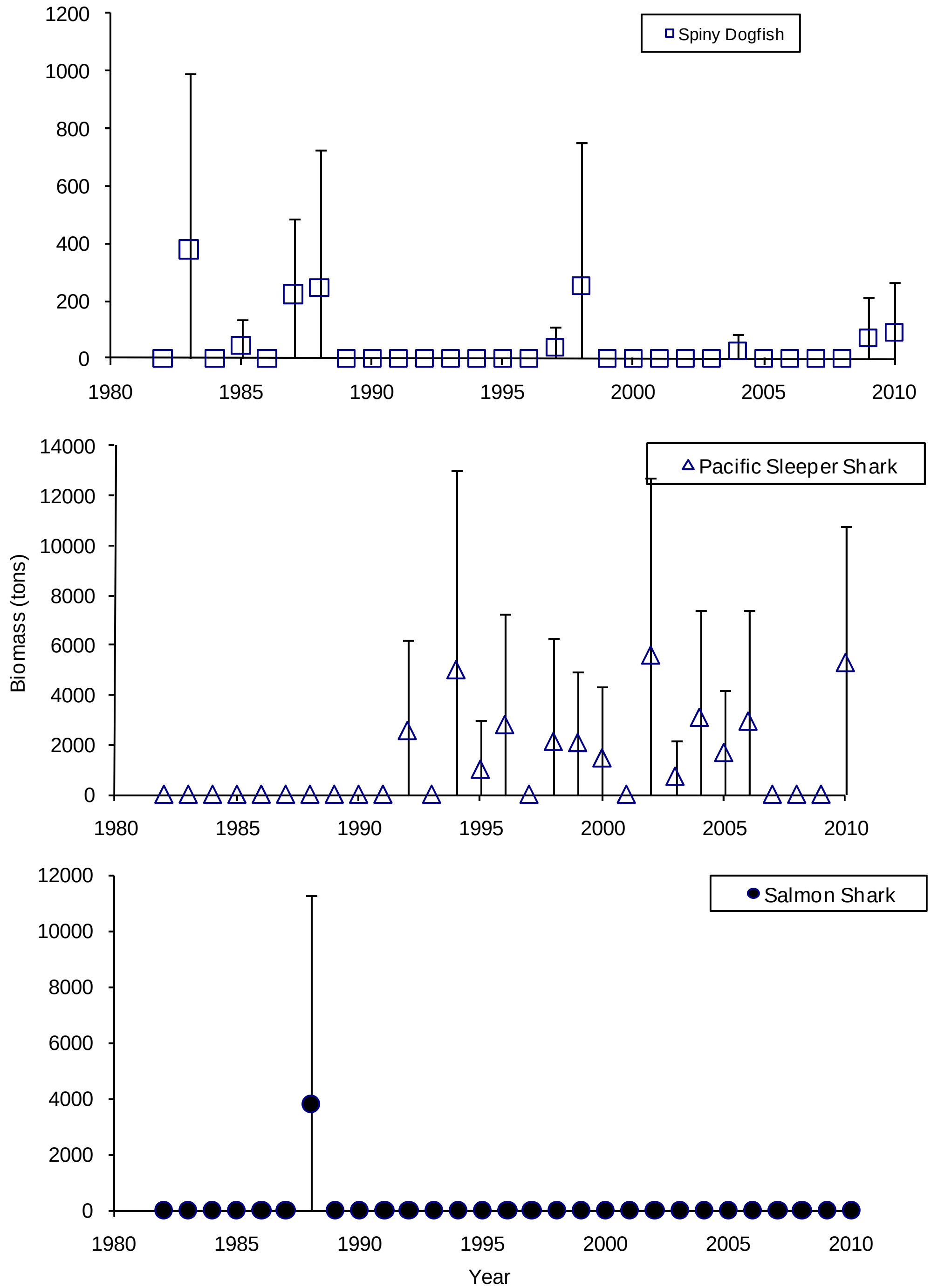

Figure 8. Time series of biomass estimates (t) in the eastern Bering Sea shelf AFSC bottom trawl surveys of spiny dogfish, Pacific sleeper and salmon sharks, reported here as an index of relative abundance. Error bars are 95% confidence intervals. Analysis of EBS shelf biomass trends is subject to the following time series caveats. The EBS shelf survey started as a crab survey in the 1960's. The survey was standardized in 1982 to its current gear type, fixed stations, and survey time period (June 1 – August 4). Prior to 1982, the set of survey stations varied greatly, and prior to 1979 the set of survey stations was very small.

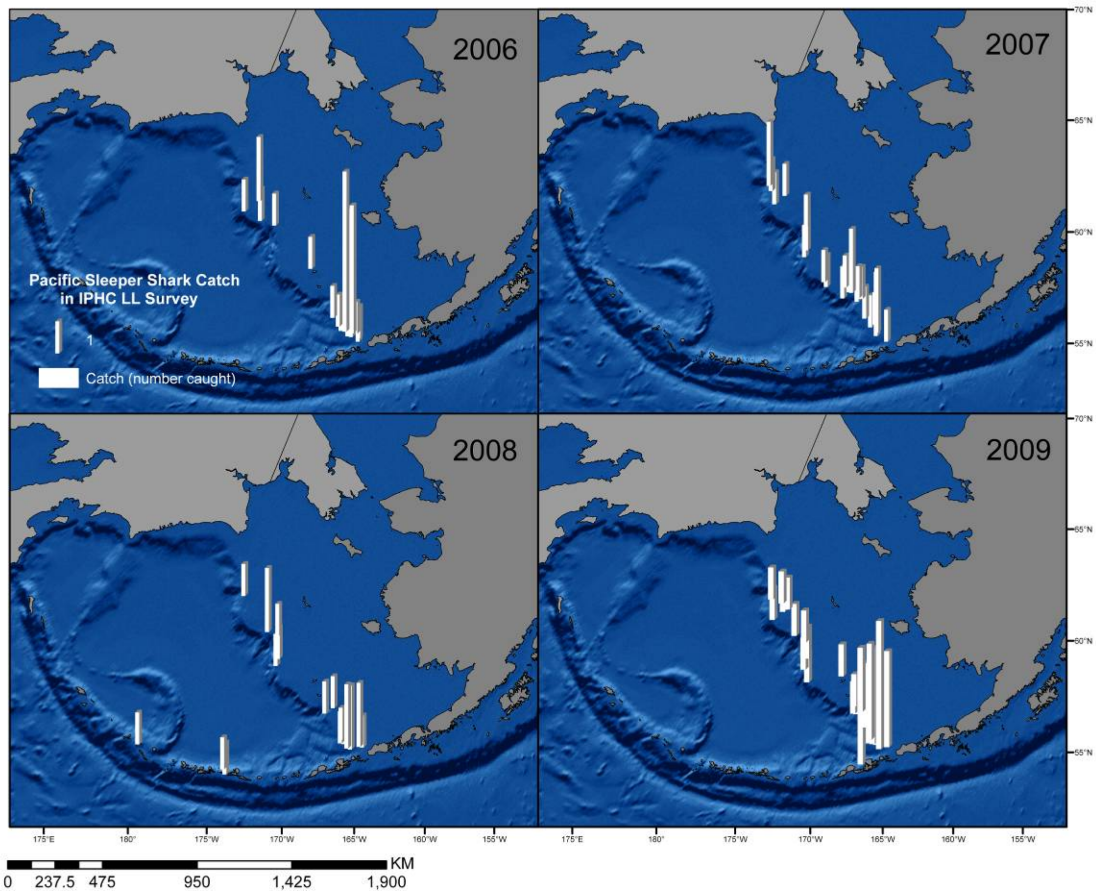

Figure 9. Spatial distribution of the catch of Pacific sleeper shark during the 2006 - 2009 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

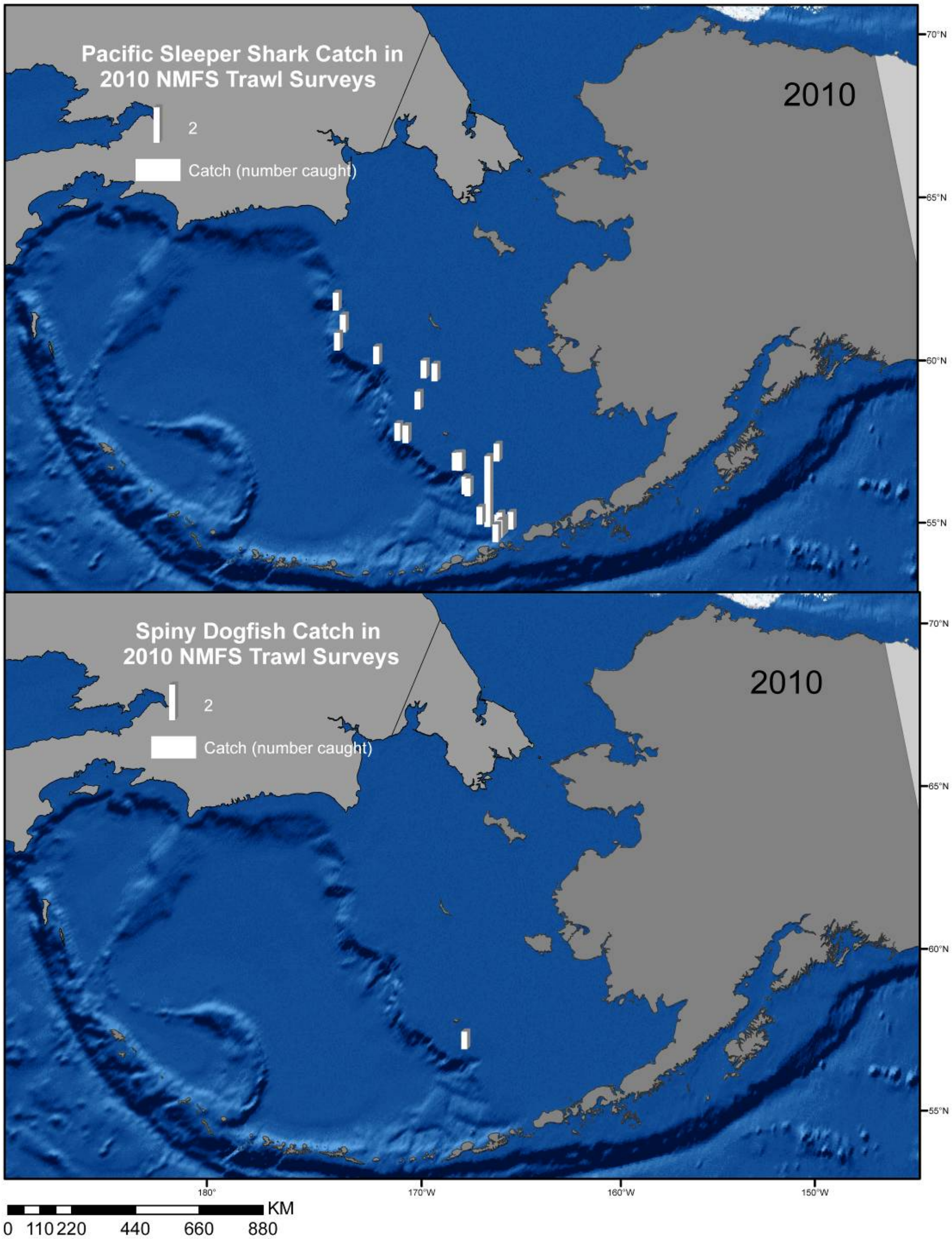

Figure 10. Spatial distribution of the catch of Pacific sleeper shark and spiny dogfish during the 2010 NMFS Bering Sea trawl surveys. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

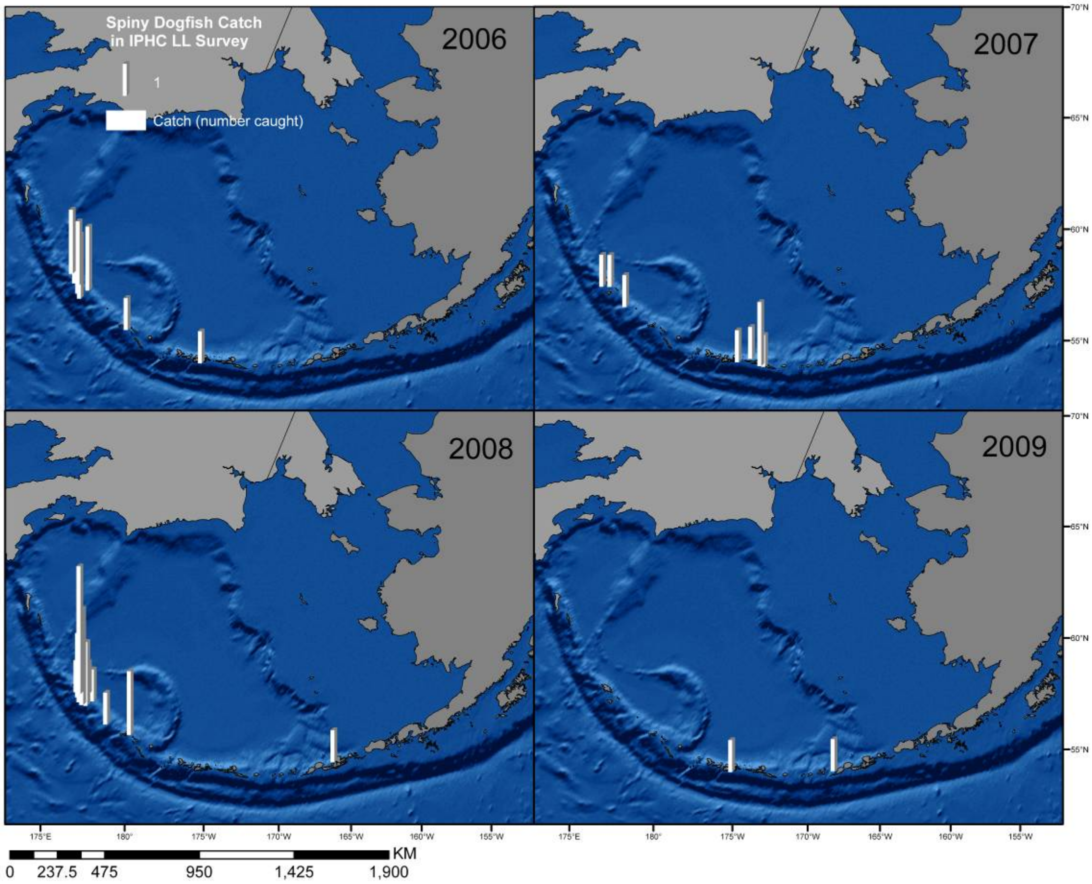

Figure 11. Spatial distribution of the catch of spiny dogfish during the 2006 - 2009 IPHC longline survey. Height of the bar represents the number of sharks caught. Each bar represents one survey haul and hauls with zero catch were removed for clarity.

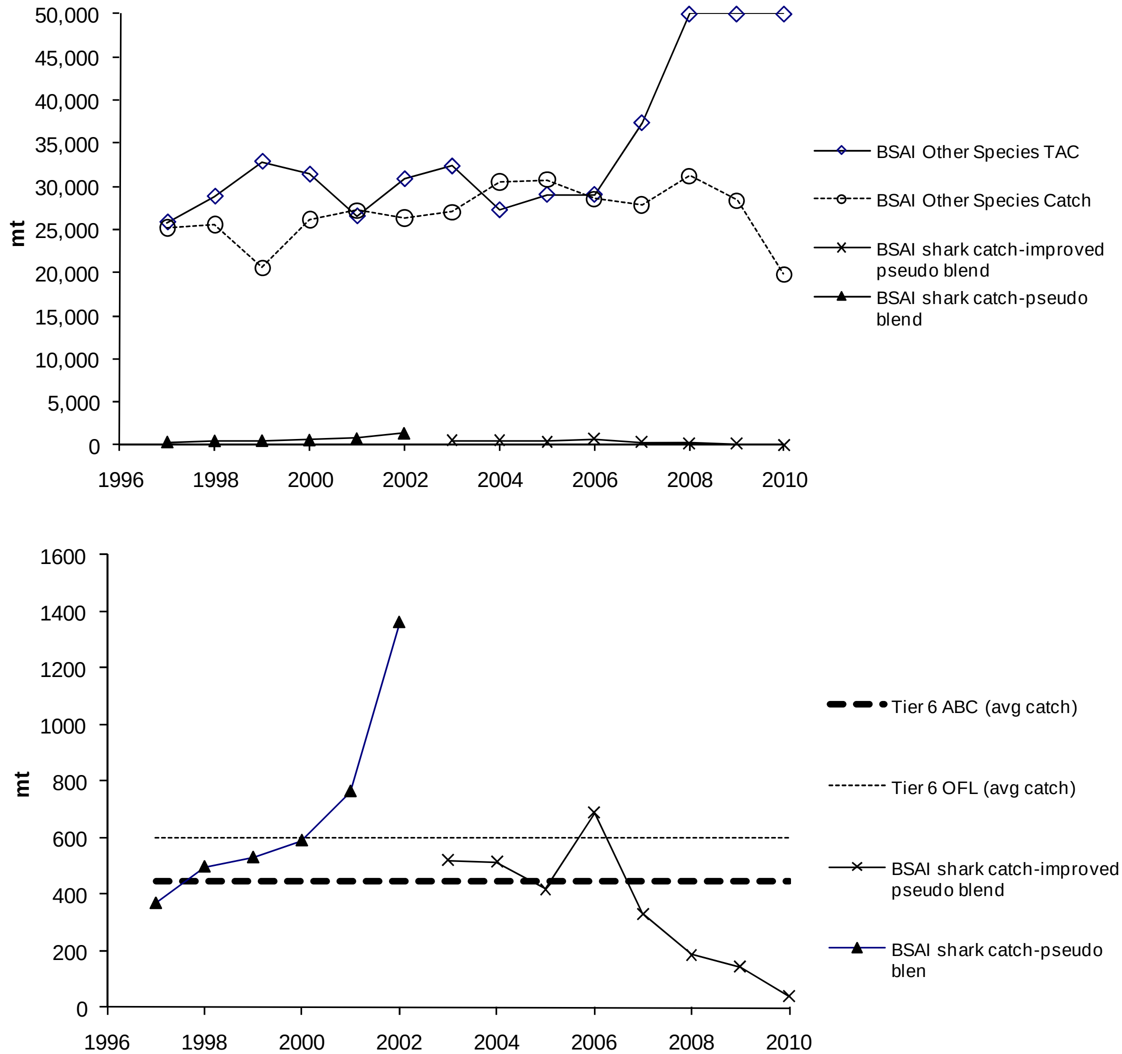

Figure 12. Top: comparison of total BSAI shark catch relative to the total Other Species catch and the Other Species TAC. BSAI total shark catch has been low relative to BSAI other species catch. Bottom: BSAI total shark catch per year plotted relative to 2010 ABC and OFL options for the BSAI shark complex under Tier 6. BSAI shark catch surpasses the Tier 6 ABC in 4 of the past 13 years.